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HENRY LANDES, State Geologist

BULLETIN No. 1

GEOLOGY AND ORE DEPOSITS
OF
REPUBLIC MINING DISTRICT

By JOSEPH B. UMPLEBY

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CONTENTS

Page
ILLUSTRATIONS 5
LETTER OF TRANSMITTAL 6

INTRODUCTION 7
  Location 7
  Field work and acknowledgments 7
  Previous work 8
  General remarks 8

CHAPTER I—PHYSIOGRAPHY 9
  Topography 9
    General character 9
    Drainage 9
    Principal features 9
    Changes in drainage 10
    Glacial features 10
  Eocene peneplain 11
    Correlation 12
  Climate 14

CHAPTER II—GENERAL GEOLOGY 15
  General statement 15
  Description of rock formations 16
    Paleozoic series 16
      Distribution 16
      Characteristics 16
      Age 17
    Granodiorites 17
      Distribution 17
      Characteristics 18
      Age 18
    Tertiary formations 19
      Relation to older formations 19
      Dacite flow conglomerate 20
        Distribution 20
        Characteristics 21
        Age 22
      Andesite flows and lake beds 23
        Earlier andesite flow breccia 23
          Distribution 23
          Characteristics 23
          Age 24
        Lake beds 24
          Distribution 24
          Characteristics 24
          Age 24

CHAPTER II—GENERAL GEOLOGY (*Continued*):

Description of rock formations—

Tertiary formations—

Andesite flows and lake beds (*Continued*): *Page*

Trachyte flow 25
Later andesite flows.......... 25
Distribution 25
Characteristics 26
Latite porphyry 27
Distribution 27
Characteristics 27
Basalt flow 28
Relations 28
Characteristics 28
Quaternary history 28
Glaciation 29
The drift 29
Stream erosion 30

CHAPTER III—ECONOMIC GEOLOGY 32
History of mining development.......... 32
Production 34
Metallurgy 34
The veins 37
Distribution 37
General characteristics 37
Minerals of the ore.......... 39
Geologic relations of the veins.......... 41
Genesis of the ore.......... 41
Effect of solutions on wall rock.......... 42
Placer mining 43

CHAPTER IV—DETAILED DESCRIPTION OF PRINCIPAL MINES.......... 44
New Republic mine.......... 44
Location 44
History and production.......... 44
Development 45
Wall rock 45
The vein 46
The ore 48
Ben Hur mine.......... 50
Morning Glory mine.......... 52
South Republic mine.......... 52
Quilp mine 53
Surprise mine 54
Black Tail mine.......... 56
Lone Pine mine.......... 59
San Poil mine.......... 62
Mountain Lion mine.......... 63
Tom Thumb mine.......... 64
Elcaliph 65

ILLUSTRATIONS

Plate. *Facing Page*

I. Town of Republic.. 8

II. Black Tail and Lone Pine mines.......................... 8

III. Geologic map of Republic mining district................. 16

IV. Dacite flow conglomerate; A, Usual texture; B, Coarse phase 24

V. Interstratification of shale with dacite breccia............ 24

VI. Quartz breccia from Lone Pine mine....................... 32

VII. Andesite flow breccia................................... 32

VIII. A, Elongation of vesicles in trachyte; B, Tufaceous lake beds 40

IX. Claim map of Republic district........................... 40

X. A, Details of crustification in ore; B, Typical appearance of Republic veins 48

XI. Vertical distribution of gold and silver in Republic mine... 48

XII. Mine map of New Republic mine.......................... 48

XIII. Mine map of Lone Pine mine............................ 59

Fig. *Page*

1. Diagram showing relation of Tertiary to older formations.... 11
2. Distribution of ore in one part of Surprise vein............. 55
3. Pattern of veins on Lone Pine and Black Tail claims......... 57
4. Diagram showing occurrence of ore in lenses in Lone Pine No. 2 vein 60
5. Vertical distribution of gold and silver in Lone Pine mine..... 63

LETTER OF TRANSMITTAL

Governor M. E. Hay, Chairman, and Members of the Board of Geological Survey:

GENTLEMEN—I have the honor to submit herewith a report entitled "Geology and Ore Deposits of Republic Mining District," by Joseph B. Umpleby, with the recommendation that it be printed as Bulletin No. 1 of the Survey Reports.

HENRY LANDES,
State Geologist.

UNIVERSITY STATION, SEATTLE, July, 1910.

GEOLOGY AND ORE DEPOSITS OF REPUBLIC MINING DISTRICT.

By JOSEPH B. UMPLEBY

INTRODUCTION

LOCATION

The Republic mining district, which is also known as the Eureka mining district, is located in eastern Washington, in Ferry county, about 20 miles south of the Canadian boundary. Definite boundaries for the district are not on record, but in general terms, it includes about six townships and has its approximate center a little west of the south end of Curlew lake. The accompanying map of a part of the district (Plate III) represents an area eight miles north and south, by seven east and west. Republic, the county seat of Ferry county, is the only mining camp represented on the map, and is the most important one in the county. It has a population of about 1,500 inhabitants and is accessible by two railroads, the Republic & Kettle Valley, and the Spokane Falls & Northern, a branch line of the Great Northern system.

FIELD-WORK AND ACKNOWLEDGMENTS

Field work was begun June 23, 1909, and was continued until July 29, 1909. By this time the geological mapping was completed and most of the problems had taken satisfactory shape; but in view of certain developments in progress and a few outstanding problems, work was resumed September 4, 1909, and was continued until September 21, 1909, although most of this time was spent in a preparation of the preliminary report.

Mr. Olaf Stromme, who assisted in the field, did a large part of the mapping and aided in some of the economic studies. During the preparation of the report many valuable suggestions were received from the professors of the Department of Geology in the University of Chicago, and for these the writer wishes to express his appreciation; particularly is he indebted to Dr. W. H. Emmons for suggestions in connection with the sections on ore deposits. The mining companies, and the residents of Republic and vicinity offered every encouragement to the work. The writer is especially indebted to Mr. Sam Richardson, county surveyor of Ferry county, whose courtesies greatly facilitated the progress of the studies.

PREVIOUS WORK

In 1904 the United States Geological Survey published a topographic sheet of the Republic area, on a scale of one-half inch to the mile and with a 100-foot contour interval.

Save for a few articles in technical journals[1], and statistical statements, there is but little literature on the camp. F. L. Ransome visited Republic in connection with his work on the International Boundary Survey in 1901, but the results of his observations have not yet been published. A statistical statement and passing note is made by W. Lindgren in Trans. Am. Inst. Min. Eng., Vol. XXXIII, p. 838. In the annual report of the Washington Geological Survey for 1901, pp. 52-60, a brief description of the district and of the principal mines is given.

Reference to work in adjoining districts will be made in the text.

GENERAL REMARKS

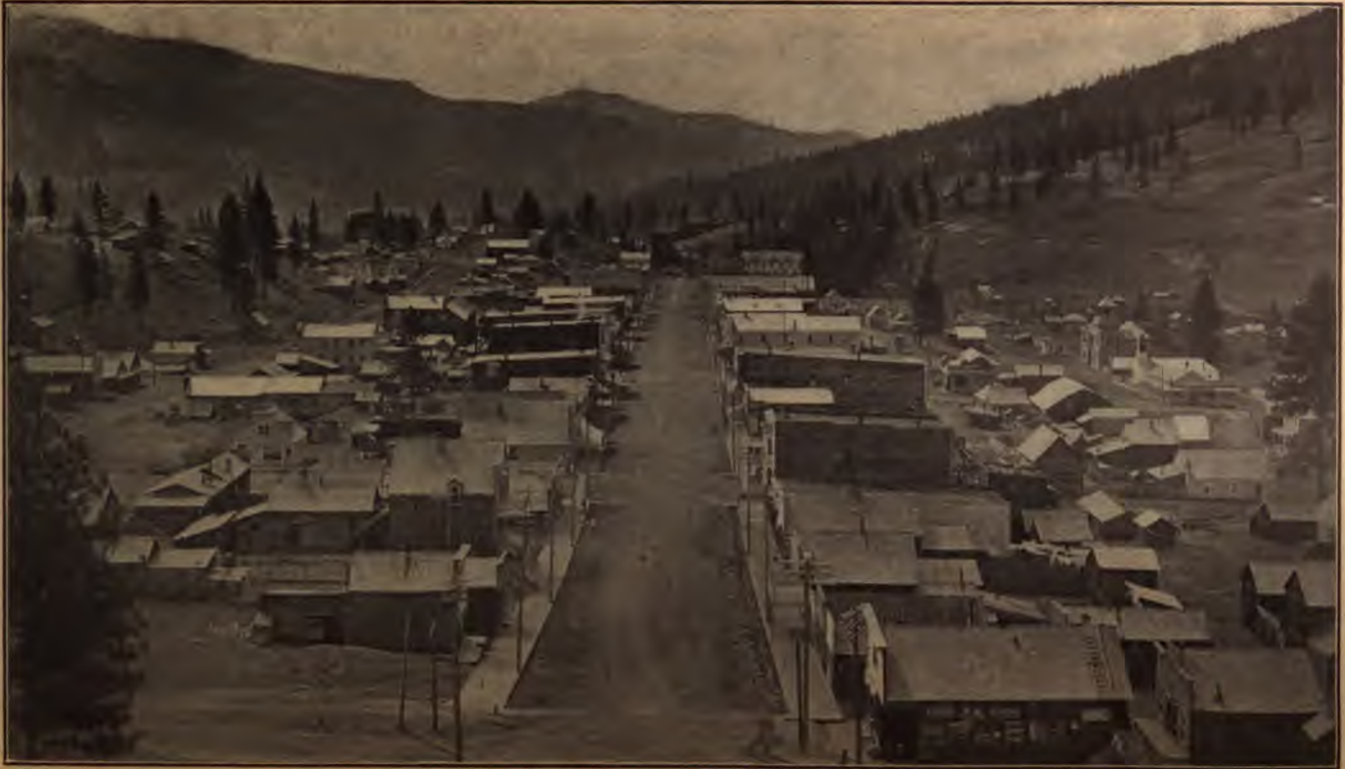
The Republic area is covered with a fairly uniform growth of medium sized evergreen trees. Although it is a district of but moderate rainfall (about 18 inches), most of the streams live throughout the year and supply an abundance of water for mining and other purposes.

The entire region is more or less thickly covered by glacial drift which, together with the vegetation, offers serious difficulties to geologic studies. The general concealment of contacts and crucial points is discouraging almost to the point of making detailed studies impossible.

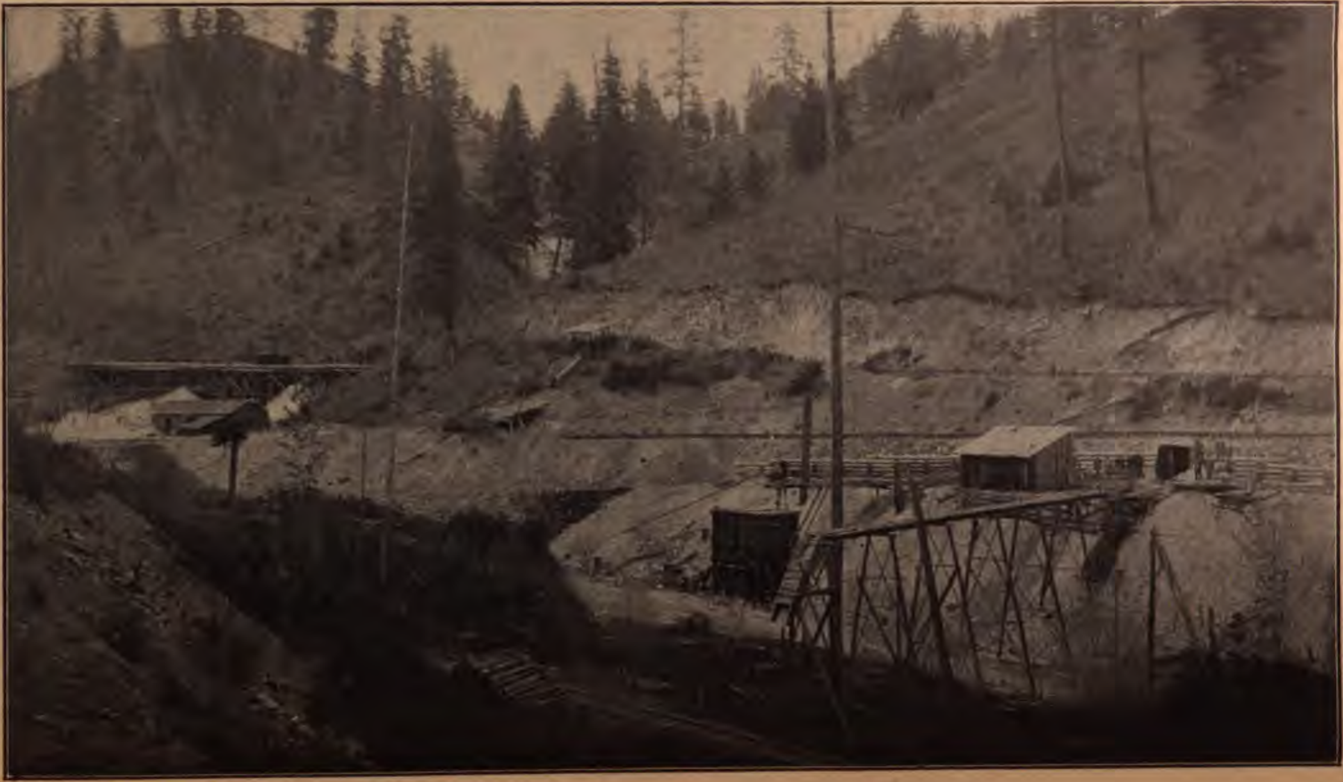
---

[1] The Republic Mining Camp, Washington, M. H. Joseph, Eng. & Min. Jour., Vol. LXVIII, pp. 635-636.

The Mountain Lion Mine, M. H. Joseph, Eng. & Min. Jour., Vol. LXIX, p. 285.



Town of Republic, Looking South. Old Mill in the Distance.



Black Tail (on right) and Lone Pine Mines in Eureka Gulch.

CHAPTER I

PHYSIOGRAPHY

TOPOGRAPHY

General Character.—The Republic district is one of bold topographic features. The mountains are of fairly uniform elevation and all have rounded tops. No broad flats exist either along the streams or on the divides, and the surface consists of almost uniformly steep slopes produced by the erosion of many branching streams, which flow in valleys from 2,000 to 3,000 feet deep. An occasional valley flat is wide enough for agricultural purposes. The larger north-south valleys in many instances present a succession of narrow terraces, at some places five or six in number.

Drainage.—The area includes the divide between Curlew creek, which flows north into the Kettle river, and thence east by a circuitous route into the Columbia river, and San Poil river, which flows south directly into the Columbia. Granite and O'Brien creeks are principal tributaries of the San Poil, while Curlew creek is fed by many small streams. Although none of the streams are large, yet they furnish abundant water for mining and domestic purposes. There are no valuable water-power sites.

Principal Features.—Within the area mapped, Granite mountain, lying six miles northeast of the town of Republic, is the highest point (5,326 feet). Copper mountain to the southwest and Gibralter mountain to the southeast, are 4,446 feet and 3,783 feet in altitude, respectively. The San Poil-Curlew valley, in which two streams flowing in opposite directions are subsequent to an older and larger stream which probably flowed to the south, is deep and flat bottomed, with its bed about 2,300 feet above sea level.

Changes in Drainage.—The San Poil-Curlew valley is steep sided with a depth of from five or six hundred to fifteen hundred feet. Within the valley the place representing the divide between north and south flowing drainage is fully as wide and well developed as any other part. This incongruity in development is further emphasized by comparing Granite creek and San Poil river valleys above the point where their streams unite. Granite creek and San Poil river are of almost equal size at their point of junction, yet the latter is flowing in a valley vastly larger than the former. These facts are interpreted to mean that the San Poil-Curlew valley was developed by an earlier and larger stream. Comparing its valley[1] with that of Kettle river, which runs south from Canada, then east and north again into Canada, it is seen to be very similar in degree of development. It is concluded, therefore, that Kettle river at one time flowed south directly into the Columbia and afterwards took its present circuitous course to the east. This change of drainage is probably one of the results of glaciation, although the area studied did not afford conclusive evidence of its cause.

Glacial Features.—A recessional moraine, in places over 200 feet high, extends east and west of the town of Republic. West of the town it is well developed and there reaches its present maximum thickness, while to the east subsequent erosion has removed much of it. The topography of this moraine in its western development is very rough, abounding in steep-sided kettles, in many instances 50 to 100 feet deep. Along the San Poil-Curlew valley terraces cut in valley train material and lateral moraines[2] are very conspicuous, while the stream is now working in a valley train. Rolling topography typical of ground moraine is widely distributed throughout the area.

---

[1] See topographic map of Republic quadrangle published by the U. S. Geol. Survey.

[2] Developed by a tongue of ice which extended down the valley from the edge of the continental glacier at the time of its recession.

EOCENE PENEPLAIN

Looking out over the broad expanse of mountain tops from any point of vantage, the irregularities caused by many deep and ramifying valleys are not conspicuous and in every direction there is striking accordance in general elevation of the mountain tops. This accordance in elevation, together with the fact that the individual mountains in some instances are limestone (Buckhorn mountain) and in others granodiorite (Granite mountain), which offer very unequal resistance to erosion, strongly suggests an old erosion surface, which now has an elevation of from 5,000 to 6,000 feet above sea level in the vicinity of Republic.

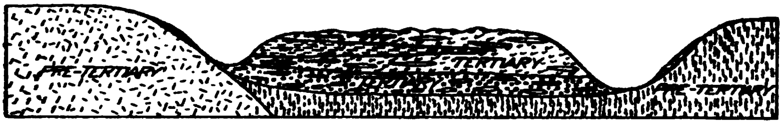


Fig. 1. Diagram showing occurrence of Tertiary formations in an old erosion valley. The surfaces at the extremes of the diagram represent an Eocene peneplain.

G. M. Dawson[1] recognizes what is probably a portion of the same surface in the Interior Plateau of Canada and describes it, in part, as follows:

> "These remnants of an old Eocene land surface are most marked in the southern half of the Interior Plateau of today, where they have elevations of from 4,000 to 6,000 feet above the actual sea level and stand 3,000 to 5,000 feet above adjacent valleys and low tracts of later origin."

Mr. Dawson regards this peneplain as Eocene both on the strength of its relation to known Miocene beds, and on the broad fact that great Eocene lakes are known to have existed to the south in Washington, Oregon and Idaho, while no evidence of Eocene sedimentation occurs in this general area, seeming to imply that the area of the Interior Plateau was land during Eocene times, and if land, evidences of a great period of erosion should be found.

---

[1] Trans. Royal Society of Canada, 1890, p. 11.

The only bearing of the present studies on the second point of Dawson's is that the extent of area where Eocene beds are absent has been increased. On the first point, however, strong support is offered. The early Miocene deposits of the Republic area lie in a great valley which was cut in the Eocene peneplain by a late Eocene or early Miocene river (Fig. 1). From this relation it is obvious that the peneplain surface is pre-Miocene, and from the fact that the early Miocene beds, which lie unconformable above earlier Tertiary lavas, occur in a deep, steep-sided valley, it seems altogether probable that the peneplain is Eocene.

CORRELATION OF EOCENE PENEPLAIN

No attempt will be made at definite correlation, but it is thought wise to record certain general features which have been suggested by the present studies. The relation of the Eocene peneplain to the Miocene deposits at Republic is quite definite (see p. 17) and analogous to that which Dawson recognized in British Columbia as shown in part by the following statement[1]:

> "There is in British Columbia some reason to suspect that a considerable amount of erosion of the surface of the Eocene peneplain occurred before the deposition of the Miocene."

And on the same page Mr. Dawson writes:

> "By an interruption of drainage * * * the great Miocene lakes of that portion of British Columbia between the Coast and Gold Ranges were first formed."

In general features the similarity between the Interior Plateau of British Columbia and the Republic highlands is suggestive of a close relation between the two areas. In opposition, however, to this general correlation is the fact that to the south, in central Washington and as far north as the Lake Chelan district, the oldest erosion surface recognized is the so-called Methow Stage of Willis, which includes beds of known Miocene age. Regarding the Methow Stage, Mr. Willis writes as follows:[2]

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[1] Trans. Royal Society of Canada, p. 13, 1890. G. M. Dawson.

[2] U. S. Geol. Surv., PP. 19; G. O. Smith and Bailey Willis, p. 71.

> "It has been identified by Russell, Smith and the writer as a feature cut upon nearly all rocks of the region, the schistose metamorphics, the Tertiary arkose sandstone, the bedded basalt flows and the pumiceous clastics of the Ellensburg formation." On page 17 of the same paper G. O. Smith states that the Ellensburg sandstone "is known definitely to be of Miocene age."

It thus appears that the Interior Plateau of Canada, although broken by mountains along the 49th parallel, may extend down into Washington and include the Highland country of Ferry and parts of adjoining counties. If this is true, this area and the central Cascade mountains of Washington are different physiographic units, and have different Tertiary histories.

Smith and Calkins[1] recognize this fact, for in speaking of the differentiation of the Cascade mountains they say:

> "An example of this is found in the occurrence of an Eocene peneplain in the Interior Plateau region, while in the Cascades peneplaination of Eocene age has not been recognized, and indeed in central Washington the Miocene lavas are known to rest upon a surface possessing considerable relief."

In connection with the last phrase in the above quotation a fact was noted, the interpretation of which is not here attempted. Columbia river south of Keller is essentially the boundary between the Eocene Interior Plateau to the north and the great Miocene Basalt Plateau to the south. The Interior Plateau stands at least 1,000 feet higher than the basalt plateau, and the lavas of the latter are at least 1,000 feet thick. Removing the basalt, therefore, we have two areas joining along a definite line and the one at least 2,000 feet higher[2] than the other, with the lower surface "possessing considerable relief."

Conclusions.—In so far as conclusions are justified it appears that the Republic area and probably a greater part of the Colville Indian reservation is a part of that physiographic unit which is known as the Interior Plateau, and which is bounded on the west by the Coast Range and on the east by the Gold Range and which extends north to the McKenzie river and, if relations here suggested be correct, it extends south to the Columbia river. South and west of this great unit is an erosion surface recognized as post-Miocene in age.

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[1] U. S. Geol. Surv., Bull. 235, G. O. Smith and F. C. Calkins, p. 90.

[2] The observations were made from a stage near Keller and are thought to be greatly minimized.

CLIMATE

The climate of Republic and vicinity is semi-arid, although it receives more moisture than many parts of eastern Washington. The temperature is not extreme either in summer or in winter. A forest growth of evergreen trees which covers the greater part of the area conserves the precipitation and distributes the runoff throughout the entire year. The following table compiled from the United States weather reports[1] gives the more important details of climatic conditions at Republic.

TABLE SHOWING WEATHER CONDITIONS AT REPUBLIC

Temperature	*Degrees fahr.*
Maximum (July '05)	102
Minimum (Jan. '09)	—32
Mean annual	43.9
Killing frost—	
Last in spring avge.	June 15.
First in autumn avge.	Sept. 3.

Precipitation (rain and melted snow)	
Annual avge.	17.96
Avge. No. rainy days	96
Avge. No. clear days	186
Avge. No. partly cloudy	74
Avge. No. cloudy	105
Prevailing wind	N. W.

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[1] Data furnished by G. N. Salisbury, Weather Bureau Official, Seattle. The observations cover the period from 1900 to 1909.

CHAPTER II

GENERAL GEOLOGY

GENERAL STATEMENT

The geologic history of the Republic district has as its great features sedimentation in the Paleozoic, erosion with minor vulcanism in the Mesozoic, igneous activity and erosion in the Tertiary, and continental glaciation in the Quaternary.

The oldest rocks exposed in the district are the metamorphic equivalents of a great series of shales, sandstones, limestones and lava flows which are of Paleozoic age, and are provisionally assigned to the Carboniferous. After the deposition of this series, the area passed through a long period of crustal disturbance which, although not developing sharp folds, metamorphosed the beds and raised the area far above sea level. Either during this period of crustal disturbance or shortly thereafter great batholithic masses of granodiorite were intruded into the Paleozoic series.

From the time of the granodiorite intrusions, which are probably of early or middle Mesozoic age, to middle Tertiary times, there was a great period of erosion which may be divided into two parts; a first, during which the entire area was reduced probably to base level (Eocene surface); and a second which was introduced by decided elevation and during which broad valleys at least 2,500 feet deep were developed.

The next rocks in order of formation are of Oligocene age, and occupy one of these broad, deep valleys. They are dacite flows, including great quantities of stream gravels. Overlying these, unconformably, are andesite breccias, lake beds, and andesite flows, all of which occur within the old erosion valley. Next in order of age are instrusive latite porphyries with which the ore deposits are thought to be genetically related.

From the time of the latitic intrusions to the Pleistoce erosion was the dominant process, although during this t there was a short period of basaltic eruption. In the Plei cene period, the Cordilleran ice sheet covered the entire area

DESCRIPTION OF ROCK FORMATIONS

PALEOZOIC SERIES

Distribution.—The oldest known formation exposed in area is a series of metamorphic rocks including slates, schis quartzites, marbles and greenstones. It is most extensively veloped (see Plate III) southwest of Republic, where about t square miles are known. East of the San Poil-Curlew vall and largely beyond the limits of the map, are extensive ar where the metamorphic series is the predominating formati Both areas are so poor in exposures that it is impossible determine detailed relations.

Characteristics.—The Paleozoic rocks are very uniform but not intensely metamorphosed. True schists are not co mon, and in many instances the limestone has not been chang to marble. Nevertheless, the series has been so disturbed th a given set of characteristics seldom persists for more than short distance in any direction. Neither bottom nor top of t series was found.

Black carbonaceous argillite is the predominant rock ty although bluish-gray non-fossiliferous limestones have a wi development. Massive gray quartzites were noted in one e posure southwest of Republic. Porphyries of intermediate an basic composition are found both as dikes and sills, apparentl intruded into the series before its metamorphism. The age r lations of the various phases of the series are not obvious fro studies in the Republic area, but to the north, at Phenix, B. C LeRoy[1] reports a section including all the above types of rock

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[1] Canadian Geol. Surv. Bull. 1072, p. 65.

which he divides into three parts with an unconformity between the upper two. His section places the argillites in the upper part, separated from the limestones and tuffs (no tuffs of this age were noted at Republic) by a pronounced unconformity, while the lower member is quartzite with intruded dikes and sills of basic porphyrites.[1] The Paleozoic beds are folded and metamorphosed, and are in marked contrast with the overlying Tertiary series in which folding is less marked and the beds are not metamorphosed.

Age.—It is not possible, on the strength of facts now known, to assign this formation to a definite place in the Paleozoic series. Near Republic the formation carries certain fossils, not well preserved, but which seem to be crinoid stems. In an exposure of limestone near the top of Buckhorn mountain in the northwest part of Republic quadrangle, several fossil crinoid stems were found which are not out of harmony with a provisional assignment to the Carboniferous. These remains, together with the lithologic characteristics of the series, suggests a correlation with the Cache creek series of Dawson,[2] which is of Carboniferous age. On lithologic grounds, however, it is thought that rocks of more than one age are present.[3]

GRANODIORITES

Distribution.—Great batholithic masses of granodiorite which cut through the Paleozoic formations are shown along the west side of the map, and are exposed a short distance beyond the limits of the map to the east. They are not exposed in the central part of the area nor for several miles north and south along the same general direction, although they may be present beneath the Tertiary lavas which are continuous as a narrow north-south belt for a distance of over 60 miles. Granite mountain, situated northwest from Republic, is a great batholith of this type, which was so denuded before Tertiary vulcanism that rocks of that age now rest on its flanks at a point more than 2,300 feet lower than its summit.

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[1] This series will be more fully discussed in a bulletin of the Washington Geological Survey now in course of preparation by the author and entitled "A Reconnaissance in Mining Districts of Northern Okanogan County, Washington."

[2] Ann. Rep. Geol. Surv. Canada, new series, vol. 7, 1894, pp. 37 B-49 B.

[3] Lithologically and structurally, there are many points in common between this series and the Calaveras formation of California, which reference to the California literature will suggest.

Characteristics.—The surface of the mass as exposed on Granite mountain is characterized by great ledges and low cliffs, usually rounded by glaciation and covered by a fairly dense forest growth. The rock is dark gray in color and made up of orthoclase and plagioclase feldspars, with lesser amounts of hornblende and biotite, and occasionaly microcline crystals. Magnetite, pyrite, apatite, titanite, and rutile are the principal accessory minerals. The rock is inequi-granular in texture, in places having scattered feldspar crystals up to one inch in length surrounded by inequi-granular material of much smaller size. At a few places the granodiorite has been made schistose by movements which took place after its solidification.

Age.—The rock of Granite mountain is clearly younger than the Paleozoic series which it intrudes, and its lack of extensive schistosity indicates that it is more recent than the dynamic movements which metamorphosed that series. It is, on the other hand, much older than the Tertiary formations which lap up on its sides, and which contain fragments of its material. Since the top of Granite mountain is probably a remnant of an old peneplain surface, the relation of the Tertiary to its exposed sides indicates that sufficient time had elapsed after its intrusion and before Tertiary volcanic activity, for erosion to remove the cover of the batholith and reduce the entire area to near sea level; for dynamic stresses to raise the area, and for erosion to develop the broad valleys in which the Tertiary formations are now found. The schistosity observed along certain zones on the mountain can be readily explained by movements known to have taken place in early Tertiary times.

From the evidence in hand it is only possible to place this period of igneous activity somewhere in the Mesozoic, and possibly about the middle of that era.

TERTIARY FORMATIONS

The Tertiary history includes several periods of igneous activity. The rock formations are divisible into two series which are unconformable. The lower is a series of dacite flow conglomerates inclosing thin beds of stratified shale. The upper is a succession of andesite flows which are separated into upper and lower groups by extensive lake beds.

Relation to Older Formations.—The Tertiary beds occupy a deep, broad valley cut in the older rocks after the elevation of the Eocene peneplain. The evidence for this relation is the geographic distribution of the Tertiary series, and the vertical distribution of contacts of Tertiary with older rocks.

The Tertiary andesite flows extend in a narrow belt over 40 miles south from Republic, and continue at least 17 miles north. The east-west distribution is limited to a comparatively narrow belt—about five miles wide at Republic.

At Phoenix, LeRoy records a similar north-south distribution of Tertiary beds which are in general alignment with those at Republic and may be in the same river valley. In speaking of these LeRoy says:[1] "They are unconformable to the Paleozoic and form a long irregular band extending from the War Eagle to the Gilt Edge claim, crossing the east side of the town of Phoenix."

Although this areal distribution of Tertiary beds is suggestive of deposition in an old valley, it is not as rigorous as the vertical distribution. The older metamorphics and granodiorites outcrop at conspicuous elevations along the east and west side of the Republic area. In the central north-south zone only Tertiary formations are found and they rest against the steep slopes of the older formations for a vertical distance of several hundred feet. (See Fig. 1). A more definite idea of the vertical distance to which they once lapped up on the older rocks is obtained by projecting the elevation of the lava series in the central part of the area across the post-Miocene erosion valley of North Fork, to the face of Granite mountain. Such projection indicates that the Tertiary series once rested against the face of the mountain to a height of more than 2,000 feet above its lowest exposed part. On the lower slopes of Granite mountain itself remnants of Tertiary material appear at several places, among others west of the Mountain Lion mine.

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[1] Summary Rept. Geol. Surv. Canada, 1908, p. 65, A. E. LeRoy.

There is a possibility, of course, that faulting may account for the relation of the Tertiary beds to Granite mountain, but the same relation is found along both east and west limits of the Tertiary formations, and nowhere is there direct evidence of faulting. In this connection it is worthy of note that the basal formation of the Tertiary contains a large percentage of well-assorted and water-worn pebbles. Some of them are of granodiorite.

From these lines of evidence collectively, it is fairly certain that the Tertiary series was accumulated in a great valley developed by erosion.

DACITE FLOW CONGLOMERATE[1]

Distribution.—Dacite flow conglomerate is exposed at various places near the bottom of San Poil-Curlew valley, along Granite creek as far west as North Fork, along North Fork and at various places along the ore zone. Except along the ore zone the formation is found only near the bottoms of the deeper valleys. Wherever it was possible to determine their dip, the beds were found to be tilted at angles varying from 15° to 80°. In an exposure near the Mountain Lion mine the beds dip 45° southwest; near the Kettle Valley station they dip 23° east; near San Poil lake the dip is nearly 60° west; and an occurrence in O'Brien Creek canyon of what may possibly be a lower member of the same formation, dips 80° west. These four out of the numerous exposures of this formation, are the only ones of value in determining their attitude, but in so far as they are to be relied upon the beds represent an anticline about two miles across in the west part of the area and a syncline in the east part.

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[1] *Flow conglomerate* is here proposed as a term to be used parallel with *flow breccia*—the two to hold the same relation to each other as obtains between conglomerate and breccia when applied to clastic beds. The parallel use of these terms makes it possible to distinguish between a flow which has picked up distinctly water worn material, and the more common type where the included fragments are angular. Rhyolite, latite, dacite, andesite, basalt, etc., according to the nature of the including rock, should precede the term.

The formation is folded, but very much less intensely than the Paleozoic, while the next following series shows little or no folding, indicating an unconformity at both top and bottom of the formation.

Characteristics.—The series is made up of lava flows which have picked up a great quantity of stream gravels and so distributed them through their mass that not one exposure in ten is free from rounded pebbles, which in most instances, constitute from 5% to 30% of the rock. The pebbles have been derived from the underlying metamorphic rocks and the granodiorite batholith. Layers of hard shale with a very subordinate amount of sandstone are occasionally[1] found in definite, often laminated, layers in the igneous rock. These vary from a fraction of an inch to five or six feet in thickness and are always sharply separated from the igneous material above and below. Occasionally wood fragments, of no value for age determinations, occur in the shale layers. A partial section of the formation is given below.

Section of Dacite Near Kettle Valley Depot

Beds concealed.		
7.	Dacite, pebbles scattered through like phenocrysts. More abundant near base	80′
6.	Shale, as in No. 4	3′
5.	Dacite, in bottom about 30% pebbles grading upwards to 1% pebbles at top. Pebbles oriented flat to shale	5′ 6″
4.	Shale, in places very sandy. No pebbles	2′ 6″
3.	Dacite, with pebbles over $\frac{1}{8}$″ making up 25% of mass. Irregular in thickness. Pebbles oriented flat to shale	8″
2.	Shale, arenaceous, firm but finely laminated. No pebbles. Contains wood fragments	10″
1.	Dacite, (lowest member exposed) resembles a coarse sandstone with 70% of tuff intermixed. Includes many slate and a few quartzite pebbles all rounded and varying up to 1″ in diam. 80% are the size of rice grains	12′
Beds concealed.		

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[1] Four exposures before mentioned.

Microscopically the inclosing rock is porphyritic in texture with the relative amount of phenocrysts to groundmass, about three to one. The principal constituent minerals, approximately in the order of their abundance, are plagioclase, quartz, orthoclase, magnetite, pyrite and apatite, with various secondary minerals. The groundmass is microcrystalline to glassy. Some of the phenocrysts are fractured and sometimes the quartz is rounded, but these features are no more conspicuous than in many other effusive rocks.

A study of the above characteristics leads to difficulties in giving the occurrence a rational explanation. The formation underlies an area of at least 30 square miles, and throughout that extent few, if any, exposures are free from the small rounded pebbles. The way in which the beds are tilted seems to imply a considerable thickness, which adds a remarkable vertical to the wide horizontal distribution of the pebbles. The presence of finely laminated shale and sandstone layers, sometimes highly carbonaceous, and usually thickly bedded, clearly indicates a succession of dacite flows separated in time by periods of quiescence of sufficient duration to allow sedimentation in small lakelets formed on the supper surfaces of some of them. The most feasible explanation of the origin of this formation seems to be that in each case the dacite lava poured out over a surface strewn with stream pebbles, the pebbles of each of the upper flows having been washed onto the underlying surface during the period of quiescence which separated the eruptions.

Age.—The degree of folding which the dacite flow conglomerate possesses and which is vastly more than that of the Eocene peneplain, might be thought to signify a pre-Eocene age. On the other hand, its known exposures, except along the ore zone where elevated by later intrusions, are all near the bottom of an Oligocene stream valley, and therefore must be younger than the Eocene. The formation is also unconformable below the next younger beds which are of early Miocene age. Because of this unconformity with the Eocene below and the early Miocene above the formation is assigned to the Oligocene.

ANDESITE FLOWS AND LAKE BEDS

Separated from the dacite flow conglomerate by a structural unconformity are andesite flows which in the following pages are divided into earlier and later because in their midst are lake deposits over 750 feet thick. Beyond the limits of the lake beds no line of demarkation was determined between the earlier and the later flows. These three divisions will be treated separately.

EARLIER ANDESITE FLOW BRECCIA

Distribution.—Overlying the dacite flow conglomerate unconformably, is a succession of andesite flow breccias which occurs along the entire extent of the ore zone and is the wall rock in many of the more important mines. In the fourth tunnel of the New Republic mine one phase of the series is well shown and has a thickness of 1,000 feet with neither top nor bottom exposed. The flows here dip about 25° east, which is higher than in the other exposures, although in the same general direction.

Characteristics.—The formation varies greatly from place to place. In the Republic mine the material is both agglomerate and flow breccia. At some places the groundmass is stratified, half indurated sand with igneous boulders of varying sizes up to 7 or 8 feet in diameter, imbedded in it in haphazard manner. In other places the matrix is firm andesite. The included boulders are chiefly andesite with a subordinate number which are sedimentary, metamorphic, or granodiorite. In still other places layers of sand and clay, only partially indurated, are found. Of these three varieties the flow breccia is predominant. Other exposures occur in the Quilp, Surprise, Black Tail, Lone Pine, Mountain Lion and Tom Thumb mines, as well as in various surface croppings. In all instances, except the New Republic mine above mentioned, the material is typical andesite flow breccia throughout.

Not all of this formation has the same genesis. The beds of agglomerate, sandstone, and shale which are included in the flow breccia in the Republic mine points to deposition of these beds by running water, and it is probable that this section is along the stream channel or possibly across an alluvial fan which was at different times a site of stream aggradation and lava flows. The andesite flow breccia which predominates in the formation, is explained by lava pouring out over a rubble strewn surface and incorporating boulders in its mass.

Age.—The formation overlies the dacite flow conglomerate unconformably and has, so far as could be determined, the same altitude as the superimposed lake beds, while in composition it is similar to the flows overlying the lake beds. From these facts it appears that this formation is the beginning of andesitic activity which continued for a long time, and resulted in many flows which, as will appear later, were separated by considerable periods of time. The flows belong to the same general period as the lake-beds, which are assigned, on the strength of fossil evidence, to the early Miocene.

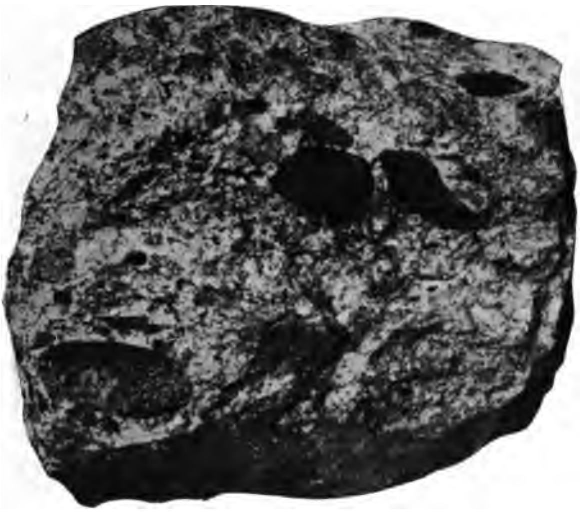
LAKE BEDS.

Distribution.—Lake beds appear at the surface along a zone very similar in extent to that occupied by the andesite flow breccia, but just east of its outcrops. The beds are structurally conformable with the underlying flows and dip easterly at an angle of about 23°. The total thickness of the deposits is not known but in an exposure south of Republic, with neither top nor bottom exposed, a thickness of 750 feet was measured.

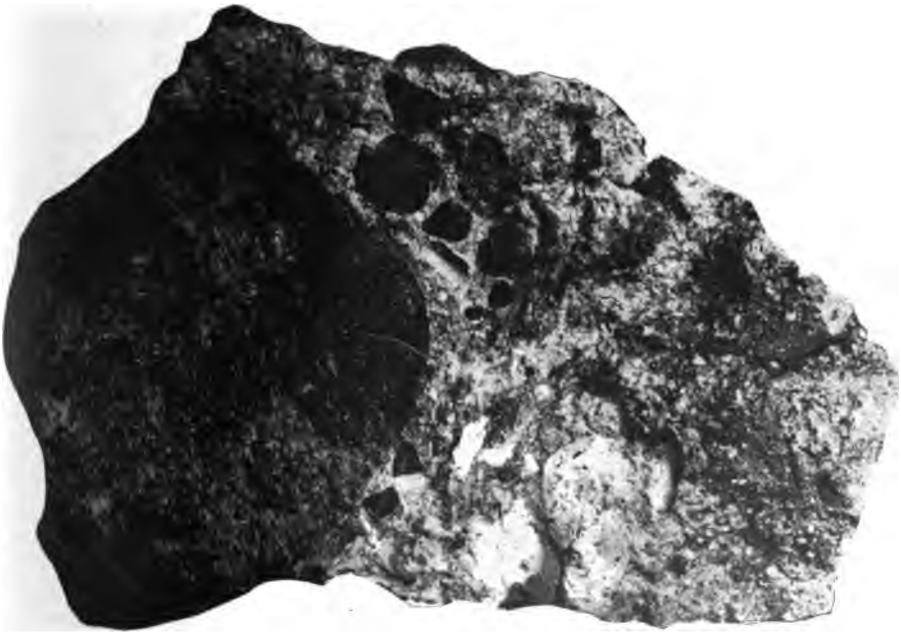
Characteristics.—The beds are usually of buff to grayish-brown color and are made up of finely laminated sandstones, shales and tuffs, all of which are predominantly fine grained. Tuffaceous material probably constitutes over one-half of the mass, since it occurs not only in distinct layers, but also as appreciable parts of the sandstones and shales. The finely laminated arrangement of the shales and sandstones points to quiet water as the site of deposition.

Age.—The beds are fossil bearing, yielding both plant and fish-remains. The plants were not determined, but Dr. C. R. Eastman examined the fish-remains and reports on them as follows:

"The smaller and imperfectly preserved fishes are difficult to determine, but the three larger ones are well characterized, and belong

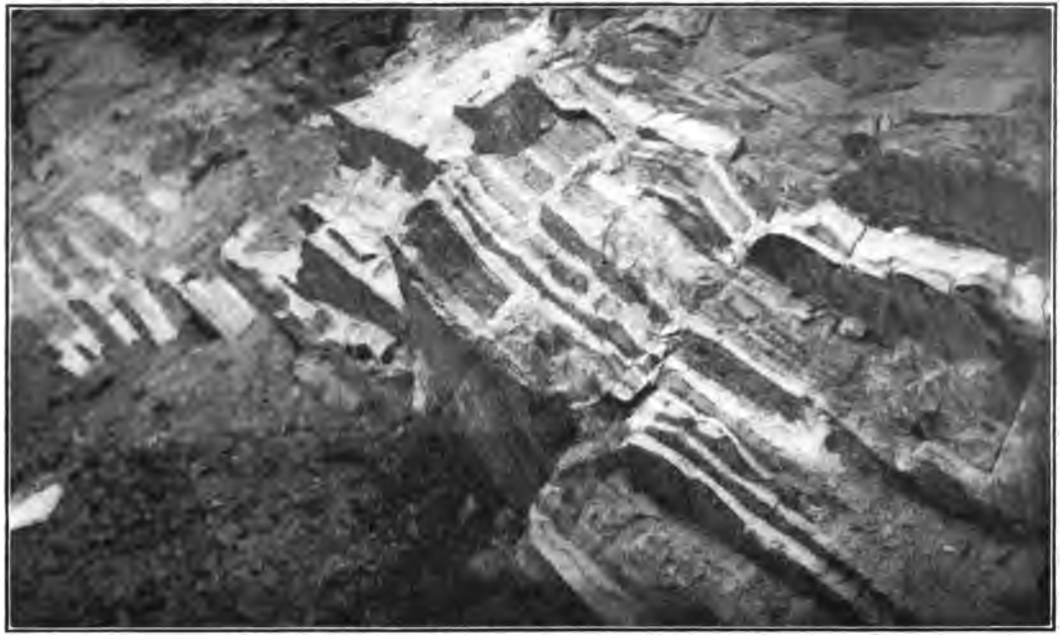


A—Usual texture of dacite flow conglomerate. The dark areas are water-worn pebbles largely from the underlying metamorphics. Actual size.



B—Coarse phase of dacite flow conglomerate. Actual size.

PLATE NO. V



Dacite flow conglomerate, including layers of stratified shale and fine-grained sandstone. Exposure near San Poil Lake.

without any doubt to the Carp family (*Cyprinidae*). * * * I feel certain, even from a brief inspection of the material, that the beds yielding these fish-remains are not of Green River Eocene, but belong much higher up in the column, perhaps approximating those at Florissant, Colorado."

In answer to the question whether or not the fossil evidence would be compatible with an assignment of the beds to the early Miocene, instead of the Oligocene which corresponds to the Florissant beds, Dr. Eastman states:

> "I should say that the evidence afforded by your material is entirely compatible with the view that the beds yielding it are of early Miocene age."

An assignment of the lake-beds to the early Miocene is in perfect harmony with the geologic relations as interpreted in the field, since it gives the entire Oligocene for the development of the broad, deep valley in the elevated Eocene peneplain, and probably for the pouring out and deformation of the dacite conglomerate, before the formation of the Miocene beds.

TRACHYTE FLOW

Inclosed in the lake-beds are two trachyte flows, the principal one of which varies from less than 10 to 75 feet in thickness. It is exposed for about a mile along the bluff south of the Tom Thumb mine, and may be readily recognized by its marked development of vesicles (Plate VIII, A).

The rock is microcrystalline in texture and composed principally of orthoclase, calcite and quartz. The calcite and quartz are secondary, largely after biotite and hornblende. No unaltered biotite or hornblende were present in the slides studied.

LATER ANDESITE FLOWS

A series of andesite flows overlies the lake beds with apparent conformity. The exact number of flows was not determined, but in an exposure south of the area mapped, seven of them can be seen in the side of San Poil valley. At this point the individual flows vary from ten to one hundred feet or more in thickness.

Distribution.—The andesite appears in the eastern and central part of the area mapped, and has been traced for 17 miles north from Republic and for about 40 miles south. Its east-west extent is not known to be over five or six miles at any place, but if it was poured out in a river valley as has been suggested, spurs to the east and west, representing the valleys of tributary streams will be likely to be found. The andesites have, in places, as on Gibralter and Copper mountains, a total thickness of 1,000 to 2,000 feet.

Characteristics.—The andesites overlying the lake beds do not contain nearly so much foreign material as those underlying them. In the upper series, however, flows of different age are recognized in many instances, by the occurrence of a zone of breccia lying above andesite which is free from foreign material. In no instance, however, does breccia make up any considerable part of the upper members. A platy structure with plates varying from one-eighth of an inch to several inches in thickness, is very conspicuous in the later andesites.

The rock has a great range in color, presenting variations in lavender, green, pink and gray shades, although the typical color of the fresh specimens is a dark gray. The pattern of the rock is fairly constant and is formed by medium sized feldspar, hornblende, and biotite crystals set more or less closely in a dense groundmass. In the fresh rock, the most conspicuous crystals are hornblende, but in weathered specimens the feldspars assume a dull white color and stand out conspicuously among the other phenocrysts.

Microscopically, the rock is porphyritic with a glassy to microcryptocrystalline groundmass. The chief minerals are plagioclase feldspars of the oligoclase-andesine variety, hornblende, pale green augite, and biotite. The accessory minerals are quartz, magnetite, pyrite, apatite, and very rarely rutile and titanite. Chlorite, calcite, and some sericite are the more important secondary minerals. Excellent resorption rims in many instances surround nuclei of biotite and hornblende. Flow structure, fractured feldspar and hornblende, and bent biotite crystals appear in several slides.

LATITE PORPHYRY

Distribution.—Latite porphyry outcrops at various places along the ore zone. Its largest exposure is along the east side of Flag Hill, where it is the surface rock over an area of almost one square mile. Smaller outcrops appear both north and south of this principal one. The rock is clearly intrusive into all the rock formations heretofore described, as shown by its influence on the dip of surrounding formations, its massive character, its metamorphosing effects on overlying beds, and its contact with all the earlier rocks.

Characteristics.—The latite porphyry is very variable in composition, but from field relations it is, nevertheless, thought to be a single rock unit. It is usually highly altered to calcite with a minor development of chlorite and sericite so that accurate determinations are sometimes impossible. The rock varies from a dark gray to a chalky white with all gradations between. Typical specimens are steel gray and on megoscopic examination, are found to be composed of both lath-shaped and stalky feldspars, hornblende, biotite and pyrite crystals set in an aphanitic groundmass with fine quartz grains as the only recognizable mineral.

Under the microscope the phenocrysts of the typical specimens are seen to be oligoclase, orthoclase, quartz, hornblende and biotite with apatite, pyrite, magnetite and some ilmenite as accessories. The groundmass is a fine-grained aggregate, principally composed of feldspar, with some quartz. Calcite, chlorite, a little sericite and rarely leucoxene, are secondary. Most of the pyrite and some of the quartz appears to be secondary. The biotite is bleached and in places has been removed.

While the above is the typical rock, marked variations from it are found. A specimen taken near the flag on Flag Hill shows no orthoclase and little hornblende, although the other minerals, both primary and secondary, are similar to the above. Another specimen from the lower tunnel dump on Knob Hill has no plagioclase but is otherwise similar to the rock first described. Between the two last named localities specimens of the typical rock occur. The typical rock is also found between the Mountain Lion and the Tom Thumb properties.

From these general facts it appears that the intrusion along the ore zone is a latite porphyry with variations to dacite porphyry on the one hand and to rhyolite porphyry on the other. The ore deposits are thought to be genetically related to this intrusive.

BASALT FLOW

Relations.—A single basalt flow with a few accompanying dikes, is exposed here and there over an irregular area of about four square miles, and has a maximum thickness of about 100 feet, although it is in general not more than 25 feet thick. The greater part of the flow lies at an elevation of about 4,000 feet, but an outlier near the Great Northern depot is only 2,500 feet above sea level. This difference in elevation of 1,500 feet is not to be accounted for by post-basalt movements, but rather by a great period of erosion between the extravasation of the andesites on which it lies, and the time when it was poured out.

Characteristics.—The exposures of this formation nearly always present excellent columnar structure. In the flow the columns are vertical or slightly inclined, while in the dikes they are horizontal. The rock is fine-grained, and steel gray to black with a distinct greenish tinge. It weathers to a brownish red color and then has a finely, though scattered, pitted appearance due to the leaching of some of the ferro-magnesian minerals.

Microscopically the rock is very finely crystalline and composed of olivine, plagioclase feldspar, usually labradorite, augite and diopside with other minerals too small to identify. The rock varies markedly from place to place, olivine and augite showing the greatest range of variation.

QUATERNARY HISTORY

The Quaternary history includes ice-sheet glaciation, and erosion by running water. No igneous activity and no dynamic movements were found to be of this age.

GLACIATION

Bowlders which are of material foreign to the bed rock where they occur, and many of which bear the peculiar striations typical of glacial action, are found at all elevations in the area, while distinct grooves on bedrock were observed in two exposures. One of these is near the summit of Copper mountain, where an area a few feet square has been exposed by an uprooted tree. It is significant, in dispelling the possibility of Alpine glaciation, that the grooves here found are almost parallel to the crestline of the mountain. The other exposure of grooves is at an elevation of 4,200 feet and near the blind road which leads into the central part of the area mapped. In both instances the direction of grooves indicates that the ice advanced from a direction 5°-7° west of north. This direction of ice movement, together with the distribution of the drift at all altitudes in the area, clearly indicates that the district was entirely covered by glacial ice, and therefore that it is a part of that great area extending north to Alaska, and west to the coast, which was covered to a great depth by the Cordilleran ice sheet in Pleistocene times. Some idea of the minimum thickness of the ice in the vicinity of Republic is gained by a consideration of the local distribution of elevations. The top of Granite mountain is a little over 2,200 feet higher than the bottom of the valley of North Fork at a point due east from it. Since the ice advanced from the north this relation of highland and lowland indicates that the ice-sheet had a thickness of at least 2,200 feet at this point.

THE DRIFT

The drift takes the form of a *ground moraine*—or that generally distributed over the area covered by the ice; a *terminal moraine*—or material deposited at the edge of the ice; *lateral moraines*—or material deposited along the sides of ice tongues which extended down the principal valleys from the edge of the ice-sheet during its recession; and *valley trains*—or material deposited in valleys by streams flowing from the ice.

The ground moraine covers perhaps 70% of the area. It varies in thickness from a few inches to perhaps a hundred feet, as on the south slope of Granite mountain and also on the south side of Deer Creek valley.

A terminal moraine extends east and west through the city of Republic, although its morainic characteristics are not so pronounced near the city as about two miles west. In the latter locality the debris is piled some 200 feet high, and there are numerous kettles and knobs with a relief of over 100 feet. East of Republic and in the city the striking terminal morainic characteristics have been partly removed, and partly modified by recent stream erosion.

Lateral moraines are conspicuous along the San Poil-Curlew valley. They are not more than ten to twenty feet high, but in many instances continue for a mile or more, with broadly regular outlines, disposed in the manner of terraces. Not all the terraces along this valley, however, are to be considered as lateral moraines, for in several places the terrace is of solid rock, while many and probably most of the terraces are due to the down-cutting of the stream in valley train material. In general, only the terraces which are rougher, more hummocky in detail, are to be considered as lateral moraines.

A valley train extends throughout the entire part of San Poil-Curlew valley which is included on the map. The thickness of the train is not known, but from the general shape of the valley it is probable that it has been filled from 100 to 200 feet with glacial debris. Those of the terraces which have been developed by the down-cutting of the stream in valley train material indicate that the filling is not now as deep by about 50 feet as it once was.

STREAM EROSION

The erosion features which have been formed in post-glacial times are strikingly inconspicuous in comparison with those which are of pre-glacial age. The drift covers a surface of bold relief, yet erosion has not been sufficient to remove it in most places, however well exposed; and indeed, several of the larger streams of the area are not flowing on bed-rock for any appreciable part of their course. Granite creek, near the Republic mill, flows in a very narrow valley which is about 100 feet deep and is of post-glacial origin. This is by far the most striking instance of post-glacial erosion in the area.[1] Its occurrence, however, at the place where a comparatively large stream crosses a terminal moraine, affords conditions favorable to erosion and meliorates the significance of the amount of erosion which has taken place.

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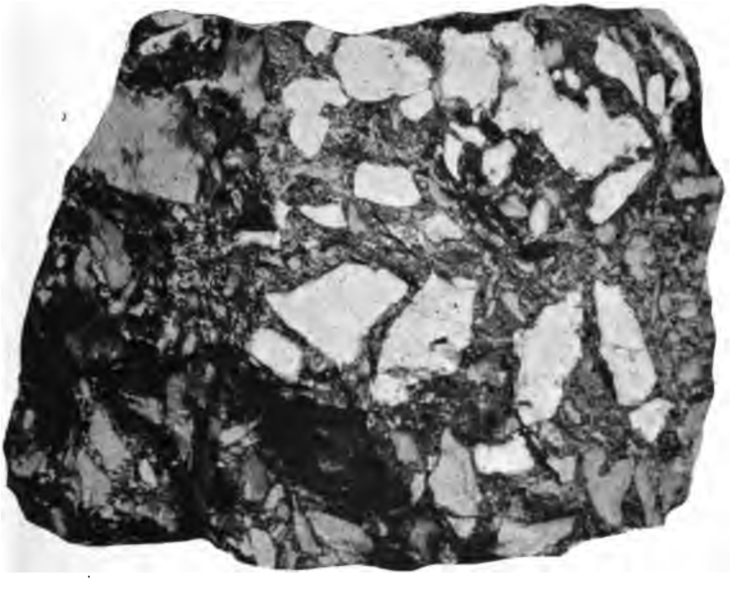
[1] O'Brien Creek Gorge is probably largely of pre-glacial age.

CHAPTER III

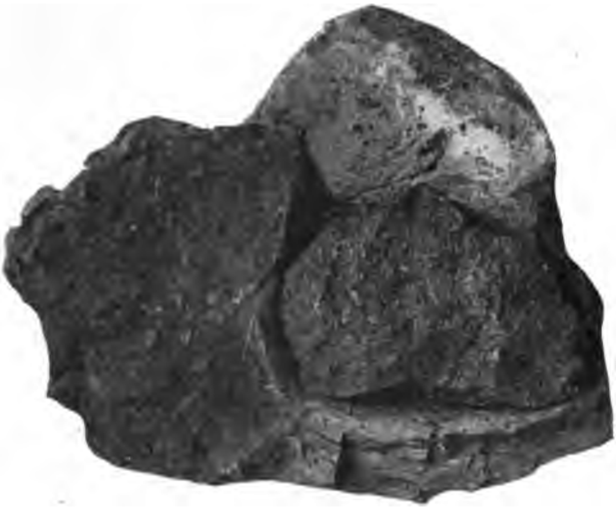
ECONOMIC GEOLOGY

HISTORY OF MINING DEVELOPMENT

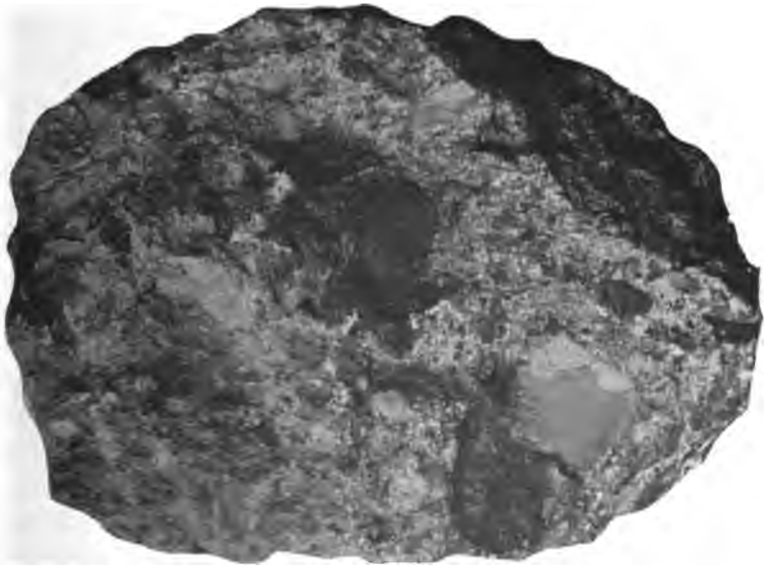
The Colville Indian reservation was thrown open to mineral entry February 21, 1896, and on the following day Philip Creaser and Thomas Ryan, two prospectors, left Rossland, B. C., for the reservation. They were grubstaked by L. H. Long, C. P. Robbins and James Clark. The two prospectors went to Bossburg on the Spokane Falls & Northern Railroad, where they outfitted and then proceeded on horseback to Nelson, a hamlet in the reservation a few miles southwest of Grand Forks, B. C. There they met George Welty, who with his brother John, had camped on San Poil creek all winter watching the ground now included in Republic camp and awaiting the opening of the reservation. Welty persuaded Creaser and Ryan to return with him and they all arrived at the Welty camp on San Poil creek February 28. The next day Creaser and Ryan located the Iron Mask, Copper Belle and Lone Pine. Closely following this the Quilp, Blacktail, San Poil, Mountain Lion and other claims were located, and on March 5 the Republic and Jim Blaine were staked out. It is worthy of note that among the locations made in the first two weeks of prospecting are included all the leading mines of the district. This accuracy of discovery is readily accounted for by the strong outcrops of the veins along the productive zone. The locators took liberal samples from the outcrops and sent them to James Clark and his associates, who made careful assays. The highest assay ran one dollar and a half gold, while none of the others showed more than a trace. Nevertheless the great strength, continuity and size of the ledges, together with the presence of a trace in each sample, were potent arguments for further investigation, and as a result Messrs. Creaser and Ryan returned to the district to



Quartz breccia from cross vein, Lone Pine mine. Later solutions introduced much pyrite not shown in cut. Actual size.



A—Andesite flow breccia. Actual size.



B—Andesite flow breccia. A common phase. Actual size.

do more development work, make other locations and secure more samples. A little development work was done on all the claims, and the next lot of samples gave returns of $4.00 in gold from the Iron Mask and $35.00 from the Lone Pine, but only a trace from the Republic, which has since become the leading producer of the camp. With further development, both the showings and values improved. Reports were so favorable that James Clark visited the camp personally and was impressed by the strength, size and continuity of the veins. He immediately interested his brother Patrick Clark and from that time on there was no lack of funds for development work. A limited amount of development on the Republic claim revealed ores running upwards of a hundred dollars in gold and a subordinate amount in silver. Also in the summer of 1896 some ore giving assays of $320.00 a ton was struck on the Lone Pine lead. Immediately following these discoveries several mining companies were organized for active and systematic development work. In May, 1898, a mill was erected for the treatment of the lower grade ore, while the highest grades were hauled by teams 80 miles to Marcus, on the Spokane Falls & Northern Railroad. Later two other mills were erected, one at the Mountain Lion mine and a large custom mill at the Republic mine, and for a time all the ore was treated locally.

Active mining continued up to the spring of 1901, when the large custom mill and also the Republic mine were closed down. From that time until the coming of the railroads in 1902 and 1903 little work was done. But with ready transportation to British Columbia and coast smelters, operations revived, and for some time shipments approximating 1,000 tons a week were made. This did not continue long, however, for owing to its highly siliceous character, the ore was found refractory by the smelters and the market became uncertain. Operations continued in a half-hearted way until early in 1909 when contracts for a period of years were made with the smelters, and operators resumed work.

About this time the new Republic Company, which had acquired the old Republic mine, discovered high-grade ore. New bodies of ore were discovered elsewhere in the camp and several leases taken. During 1909 shipments were regular and there was a gradual return to prosperity. A reduction in freight rates to the Puget Sound smelters of from $1.25 to $1.50 a ton increased greatly the amount of marketable ore in the camp.

PRODUCTION

The total bullion production of the camp cannot be stated with accuracy, but from the best information available it is about $2,000,000 and of this amount approximately 90% in value has been gold, and the remainder silver. The great losses of early mining methods makes the actual production of the veins very much higher, but the amount lost cannot be approximated. The New Republic mine leads in total production with about $1,400,000, while the Quilp, Mountain Lion, and Lone Pine hold about equal rank and represent most of the remainder.

METALLURGY

With great deposits of ore which runs about $7.00 per ton, and *comparatively limited* amounts which run over $12.00, the treatment of the ores becomes the most essential factor in the future prosperity of the camp. Many processes have been tried, but without great success. In view of the importance of the metallurgical treatment of the ore it is thought wise to record the known facts in this connection.

Early amalgamation tests showed that even on ore assaying upwards of $100.00 it was seldom possible to get an extraction of much more than 40%. Various experiments made with cyanide led to the adoption of the Pelatin-Clerici process and the erection of a ten-ton test plant. This was later increased to 35-tons capacity and although the extraction was better than by previous methods, especially when the ore was crushed to 120 mesh, still the saving on $30.00 ore fell as low as 70%. The loss and cost of treatment made the process prohibitive on ores running less than $25.00 and hence was abandoned.

In the fall and spring of 1899 and 1900 the Mountain Lion

Gold Mining Company built a 100-ton mill,[1] using plate amalgamation followed by the McArthur-Forrest cyaniding process. The extraction (a bullion recovery of 64% gold and 35% silver) fell much below the anticipations of the company, and in view of railroad transportation to smelters, which was expected in the near future, the mill was closed.

Messrs. T. M. Chatard and Cabell Whitehead[2] made a series of experiments on Republic mine ore which from their description probably came from the upper workings, and for that reason is only in small part applicable to the deep ores of the camp. They found only a minute trace of sulphuretts, no free gold, no arsenic, antimony, tellurium or selenium and indeed "there appeared to be no chemical reason why gold should not be easily extracted by cyanide. Moreover, when a sample of the ore was treated with hydrofluoric acid, the gold in the residue was clean and bright, and under the microscope showed indications of crystallization." Ore of various sizes was subjected to cyanide solution and the fact of increased extraction with fine grinding was established. It was found that treating the ore with acid freed the gold while alumina, oxides of iron and lime were contained in the solution after the ore had been treated. Thinking that lime carbonate was the masking agent, calcining was substituted for the acid bath and savings of 94.60% gold secured. It was found, however, that some of the gold contained no lime carbonate and yet roasting was equally beneficial. This fact, after a series of corroborative tests, led the authors to the conclusion "that the material which envelops the gold and prevents its dissolving in the cyanide consists mainly of the hydrated oxides of alumina and iron."

The above experiments and conclusions are very suggestive, but it is thought that they can only be applied to the upper workings where secondary agencies have been operative in destroying the primary minerals. The authors describe the ore as

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[1] An article by Fritz Cirkel, Eng. and Min. Journal, Vol. 85, p. 246.

[2] Trans. A. I. M. E., Vol. 30, p. 419 *et seq.*

"grayish-white lumps of chalcedonic material, intermixed and coated with a soft friable substance having the appearance of amorphous silica." It is noted that nothing is said of the bands of metallic to submetallic luster which are the conspicuous features of high-grade ore found in the workings of even moderate depth (say 100 feet), and from this fact it is to be inferred that the samples sent to Chatard and Whitehead were from comparatively near the surface. On roasting the high grade ore of the lower levels strong sulphur, antimony and selenium fumes are given off, indicating that in the primary ore sulphides are present. Future metallurgical tests should carefully take into account the two types of ore.

In March, 1899, the Republic Consolidated Gold Mining Company succeeded the old Republic Company and shortly thereafter erected a 200-ton mill, the essential features being fine grinding and roasting followed by cyanide. The mill received its first ore in October, 1900, and continued to run, most of the time at part capacity, until July, 1901, when it was shut down on account of an insufficient ore supply. The lack of supply was due principally to three causes; first, the Republic mine reached a place where it was unable to supply its proportionate amount of 100 tons per day; second, the charges for treatment of custom ores varied from $5.50 to $8.25 per ton, which, added to mining and haulage expenses, was prohibitive on most ores of the camp; third, the ores of the camp usually, if not universally, increase in silver with depth, and since the method of treatment allowed for the payment of only 50% of the assay returns on silver, this also acted as a condemning argument against the process. The mill went into the hands of the receiver some months later, and has since been dismantled.

The Mountain Lion Company during the winter of 1903 and 1904 installed the Hendryx process, but the results did not come up to expectations and the mill was closed.

The mines which have been operated with even moderate degrees of success in recent years have depended on the smelters for treatment. British Columbia and coast smelters have offered a market which, although somewhat spasmodic, has, withal, been very satisfactory in view of the highly siliceous character of the ore. Within the last two years the market has become much more stable, so that the smelters are willing to make term contracts for definite amounts of ore, which is largely used for convertor linings.

The present outgoing tonnage of the camp is approximately 125 tons per day, most of which is being shipped to the Tacoma smelter, the minimum freight and treatment rate being $5.50 per ton.

THE VEINS

Distribution.—The productive belt at Republic is included in an area about one mile east and west by five and a half miles north and south. The veins may be divided according to direction into two systems. Those of the principal system vary in strike from 7° east to 30° west of north, and, with the exception of the Mountain Lion, dip east. It is made up of from one to four approximately parallel veins which vary from less than 100 feet to over 4,000 feet in length, while as a whole it has a known extent of some four miles. The veins of the second system strike from 30° to 60° east of north, and with few exceptions dip southeast. These veins have never been found to be continuous for more than the length of a claim and are in most instances much shorter. Although in many places apparently cut off by the north-south veins they are thought to be essentially contemporaneous with them in origin. The Tom Thumb veins have been provisionally assigned to this system.

In addition to these two general classes a few narrow veins having a strike intermediate between the above two are found on the west slope of Copper mountain. They have not proven to be of economic importance, and although mentioned again under the next topic, they are not given special attention in this paper.

General Characteristics.—The veins are strong fissure fillings having an average width of about 3½ feet. The unaltered vein material is a firm white quartz with wavy ribbons of a bluish-gray cast distributed in parallel bands. Broadly, these are parallel to the walls of the veins, but in detail they are very irregular, and are frequently concentrically crustified. The ore is generally altered for 30 to 100 feet from the surface, and here has a dull chalcedonic appearance with banding rather ill defined, and a mixture of earthy material and colloidal silica distributed in minute cracks in the quartz. The outcrop of the veins, where free from moisture, is of firm white quartz except where iron stains give a reddish-brown appearance. It is in some places slightly porous, in others decomposed to a mealy, chalky mass, but in most places it is hard and vitreous and stands in slight relief above its surroundings.

The veins are made up of quartz, chalcedony, opal, calcite and adularia, carrying inconspicuous amounts of pyrite and chalcopyrite, with silver, and possibly gold, in association with antimony, sulphur and selenium. The only gangue mineral which varies conspicuously in amount from place to place is calcite, which varies from nothing up to 25% in the productive veins, with probably 5% as an average, while in one non-productive vein on Flag Hill calcite makes up perhaps 75% of a three-foot vein. Values are in gold and silver and vary from a trace to several thousand dollars a ton; the workable values occurring in shoots which, as a rule, pitch to the south at a high angle, while the high grade is found in kidney and lens-shaped aggregates within these shoots. Within a given shoot the ratio of gold to silver usually decreases with depth.

The vertical distribution of values in the Republic mine is shown in Plate XI, which may be considered as fairly representative of the entire camp.

The veins are not generally fractured, and since the country has been recently glaciated, the leached zone is less extensive than in many mining districts; indeed in several instances returns of over $100.00 a ton have been secured just beneath the lichens.

The veins on the west side of Copper mountain are narrow and only persist for short distances. They contain pyrite, chalcopyrite, arsenopyrite, galena, and zinc blende in a quartz-calcite gangue. Several hundred feet of development work has been done on some of the veins, but as yet no deposit of economic importance has been discovered.

MINERALS OF THE ORE

Perhaps the most striking feature which a cursory examination of the Republic ores reveals is the extremely barren appearance of the quartz. Assays show that the values occur in the bluish-black metallic to submetallic ribbons, but a careful microscopic study of these shows only a disseminated aggregate of small opaque specks which as a rule are undeterminable. Scattered grains of pyrite and chalcopyrite are the principal exceptions, although one small crystal of fluorite and two others which resemble titanite were noted in the slides. A partial analysis was made by Mr. S. G. Dewsnap, of Seattle, of a pulp made by mixing specimens of high grade which were taken from the intermediate levels of the New Republic mine. The results of the analysis follow:

Partial Analysis of Selected Republic Highgrade Ore by S. G. Dewsnap.

Silica	47.62
Alumina	9.73
Iron	4.94
Copper	9.74
Sulphur	8.23
Selenium	5.26
Magnesia	trace
Arsenic	trace
Fluorine	not determined
Water of composition	not determined
Gold	2.81
Silver	7.34
Ca Ti and earths	.14
Tellurium	.4 to 2.12 in dif. samples of same pulp

This combination of elements together with certain blowpipe tests, suggests that the silver is partly in the form of silver selenide and partly as gray copper. Some of the gold is free but most of it is probably combined with the selenium and tellurium. From the relative amounts of selenium and tellurium in the analysis it appears that the selenide is much the more important form. The minerals certainly identified are listed below.

Adularia.—This vein-forming potassium mineral was found in various slides of ore, especially in those of the New Republic mine, where the mineral occurs as linings in the little vugs of microscopic size and associated with quartz crystals on drusy surfaces. It is also found as a replacement of feldspar in several of the slides of wall rock.

Calcite.—Carbonate of lime occurs as a subordinate part of the gangue of most of the veins. It is very conspicuous as a replacement in the wall rock.

Chalcopyrite.—The copper iron sulphide occurs in microscopic sizes very sparsely scattered through the richer ore. It is usually massive, although in some places there are suggestions of crystal outline.

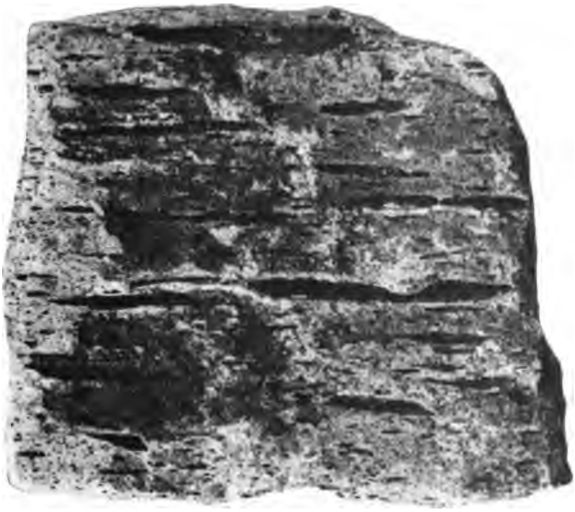
Gold.—From the metallurgical studies it appears that about 40% of the gold is free, while the remainder is in a combined state; probably as a gold-silver selenide. Some placer gold is reported to have been worked on Granite creek.

Gypsum.—Calcium sulphate occurs in a few places as secondary deposits in both the vein and the country rock.

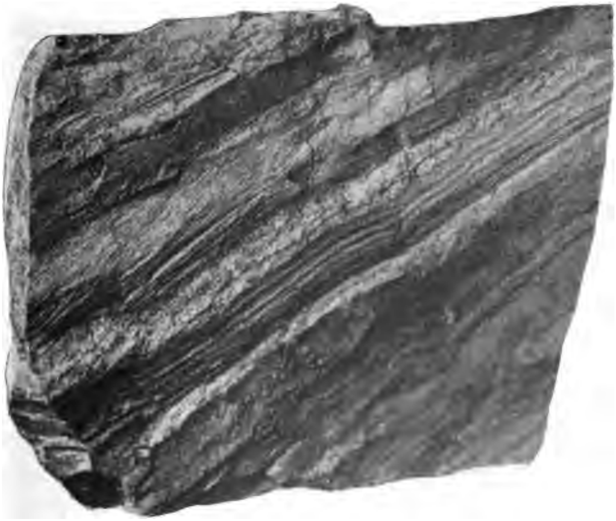
Iron Oxide.—The red oxide of iron is found as a precipitate from the mine waters, especially in those places where the deposits are in flow breccias. It occurs also as a stain on the quartz of the outcrops.

Malachite.—Copper carbonates are very rare, but malachite stains are found in certain places, as for example, near the winze in the New Republic mine.

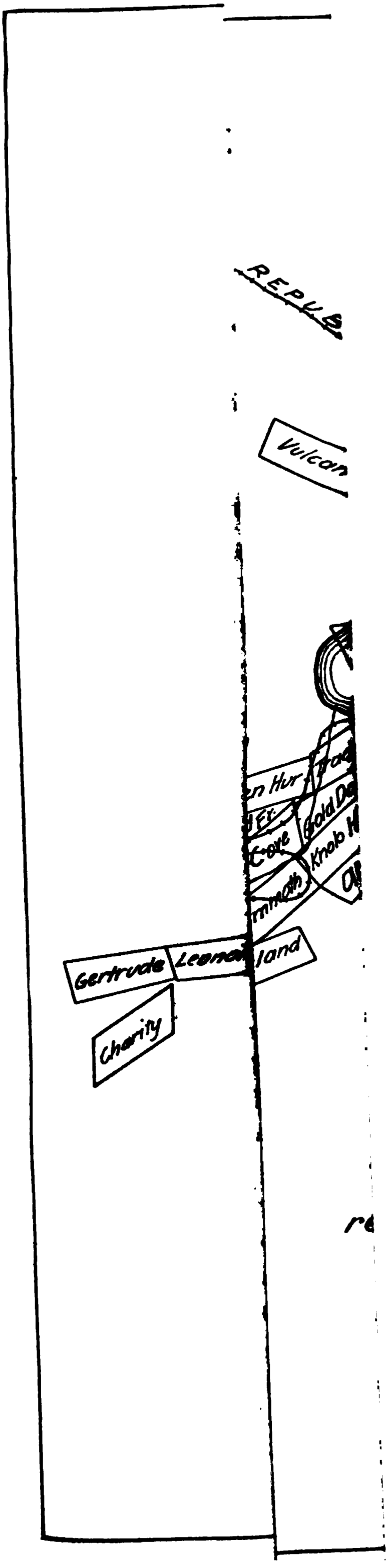
Pyrite.—Pyrite occurs in the veins and in the country rock, but is never conspicuous in the former, while in the latter it is found in almost every specimen. In the country rock it is usually in cubes and less frequently as irregular masses. In the veins it occurs massive, or as crystals which are predominantly cubes, but occasionally octahedrons and pyritohedrons.



A—Elongations of vesicles in trachyte. Actual size.



B—Showing the degree of stratification in the tufaceous lake beds. The white layers are tuff. Actual size.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Quartz (including chalcedony and opal).—The productive veins run from 75% to 97% silica. The quartz is usually milk white to clear, and in general is concentrically crustified.

Silver.—A small amount of native silver is reported from the lower levels of the Quilp mine.

GEOLOGIC RELATIONS OF VEINS

The Republic lodes are all inclosed in formations of Tertiary age. They cut latite porphyry, dacite flow conglomerates and andesite flow breccias. Following is a tabulation of the more important veins (given by mines) with their inclosing rock and approximate total production.

Table Showing Geologic Distribution of Productive Veins at Republic.

Name of Mine.	Approximate production.	Latite Porphyry.	Andesite flow breccia.	Dacite flow conglomerate.
South Republic	$10,000(?)	X		
New Republic	1,400,000		X	
Quilp	275,000		X	
Surprise	100,000		X	
Black Tail	15,000(?)		X	
Lone Pine	140,000		X	
San Poil	10,000(?)	X		
Ben Hur	65,000	X		
Mountain Lion	200,000(?)		X	
Tom Thumb	15,000(?)		X	
Morning Glory	40,000			X
Elcaliph	15,000(?)			X

GENESIS OF THE ORE

The open fissures in which the vein matter was deposited were probably all formed at approximately the same time. Their arrangement and distribution relative to the latite porphyry intrusion, suggests that the fissures resulted from stresses set up by activity in that body. Their contemporaneous origin is also suggested by the fact that the east-west lodes abutt against the north-south lodes, but in no observed case continue on the opposite side. In two places—Lone Pine mine and south of Tom Thumb—quartz breccia of vein material is cemented by primary ore (Plate VI). This is, however, thought to be only a minor episode in the vein forming period.

The depth at which the veins were formed cannot be absolutely determined, although geologic relations suggest a fairly definite maximum. The veins cut a series of formations which have accumulated in a post-Eocene peneplain valley. The upper surface of these deposits along the mineralized zone has at present an altitude of 3,200 feet above sea level, which is 1,800 to 2,300 feet lower than the old peneplain surface. From these relations, and since there is no evidence that the beds now found in the old valley ever lapped out onto the peneplain surface, it follows that the veins were formed at a depth of less than 2,500 feet.

The veins are thought to be genetically related to the latite porphyry both by reason of their similar distribution, and the apparent relation between the strains which made the fissures for the veins and the intrusion which bowed up the rocks along the zone where the veins occur. It will be noted that some of the veins occur in the rock from which they are thought to have been derived. This relation, however, is in perfect harmony with the principles of ore deposits as now known, the idea being that the solutions remained in the magma after its outer part had solidified and were expelled at a later time, probably by the forces of crystallization in the deeper, cooling part.

The solutions were hot ascending waters rich in silica, lime and potash, and carried subordinate amounts of sulphur, iron, copper, gold and silver, selenium, and a little tellurium and fluorine.

EFFECTS OF SOLUTIONS ON WALL ROCK

Broadly, the effects of the solutions on the wall rock are silicification near the vein, and calcification farther away. In the New Republic mine silicification near the vein is very conspicuous on the fourth level, where loose agglomeritic material up to within about 200 feet of the lode, grades into a compact siliceous mass from there on to the vein. Calcite appears in most slides taken within a mile of the lodes and in some which were taken much farther away. Microscopic examination shows that calcite has been developed after feldspar and hornblende, and chlorite after hornblende and biotite. The biotite crystals have been bleached and secondary pyrite is very extensively developed.

PLACER MINING

In the spring of 1900 extensive placers were reported on Granite creek above the outcrops of the known ledges, and claims were "staked for fifteen miles up the creek." The pay streak was a fifteen-inch gravel seam on a clay bedrock. A total production of $8,000 is claimed, although this amount is open to question. The claims were worked for one summer, but since they were patented no work has been done.

SIMILAR DEPOSITS

There are no deposits known in the United States which are altogether like those at Republic. Their striking feature is the great amount of selenium in the ore, along with appreciable amounts of tellurium. The deposits at Tonopah carry selenium but have no tellurium. At Goldfield both selenium and tellurium occur, but not in very conspicuous amounts. Aside from these two camps and Republic there are no known selenium ores in the country. Selenium has been found at a few places in Mexico, and the Waihi mine in New Zealand is one of the best known foreign deposits.

In the great amount of calcification which has taken place in the wall rock near the veins the deposits resemble the California gold veins, but in the general nature of the veins themselves, and in the type of the inclosing rocks the Republic lodes are most like those of the Great Basin province, and it is with Tonopah and Goldfield that they can be most nearly correlated. Like the Great Basin deposits, the Republic veins have yielded few placers.

CHAPTER IV

DETAILED DESCRIPTION OF PRINCIPAL MINES

The various ore bodies are very similar in most respects, but for some of them the wall rock is andesite flow breccia, for others latite porphyry, and for still others it is dacite flow conglomerate. The New Republic, Ben Hur, and Morning Glory mines are described as types of the first, second and third respectively. Following the description of these, the more important mines are taken up in the order of geographic location, beginning at the south.

NEW REPUBLIC MINE

Location.—New Republic mine is situated on the west side of Granite creek a short distance south of the town of Republic, and at an elevation of about 2,500 feet above sea level. The area embraced by the property is nearly co-extensive with Republic hill, which is an elongated mound trending north-south. The hill is carved out of the east slope of Copper mountain and stands as a topographic feature by reason of the vein, which being more resistant than the country rock, forms the crest line of the hill.

History and Production.—The history of New Republic mine is essentially the history of the camp. The claim was located early in March, 1896, and in June, 1897, active development was commenced. In May, 1898, a 30-ton mill of the Pelatin-Clerici type was erected, which enabled the treatment of considerable quantities of ore that was not sufficiently high grade to justify a haul of eighty miles to Marcus—the nearest railroad station. In March, 1899, this plant was dismantled to make room for a 200-ton mill which was designed for cyaniding the roasted ore. This mill was in operation for less than a year. Both of the mills were expensive to operate and did not make a satisfactory saving. Thus far smelting seems to be the most satisfactory treatment for the ore, and for several months past the entire output has been shipped to the Tacoma smelter, which makes a freight and treatment rate of $5.50 to $6.50 per ton, depending upon the ore.

The total production of the property is said to be about $1,400,000—over one million of which was produced between the years 1897 and 1902. During 1909 the mine produced from $10,000 to $15,000 per month.

Development.—The property has nearly two miles of tunnels, drifts, winzes, raises and cross-cuts. The policy of development has been a progressive effort to acquire greater depth without sinking a working shaft. No. 1 tunnel enters the hill from the west, and cuts the ore at a point 125 feet below the surface. The ore on this level having been blocked out and its continuance in depth determined, No. 2 tunnel was driven westward on a level 78 feet lower. No. 3 tunnel was then driven westward on a level 180 feet lower than No. 2; and shortly thereafter, No. 4 was driven in the same direction from a point 180 feet lower than No. 3. The latter tunnel, which is 2,240 feet long, is large and well timbered, and gives a total depth on the vein of 565 feet. From this level a winze, sunk on the ore, connects with the fifth or lowest level. The amount of mining from the various levels is shown on the stope sheet, Plate XII.

The method of mining is simple overhead stoping—power drills being used. At the mine the ore is passed over grizzlies and the fines loaded into cars direct, while the oversize is handpicked before shipment.

Wall Rock.—The wall rock of the vein is well exposed in all four tunnels. In the main, it is an andesite flow breccia which alternates with layers of waterlaid material. The wall rock is a part of the great Tertiary series, largely lava flows, which rests directly upon rocks of vastly older age. In the parts of the mine which were accessible at the time of the investigation no igneous rock younger than the flow breccia was noted, but from surface relations there is some reason to think that latite porphyry lies at no great depth below the present workings. This inference is based on the occurrence of intrusive latite porphyry on the adjoining claim to the southwest and also near the G. N. R. R. bridge immediately north of the New Republic property.

The strike of the sedimentary layers which are associated with the flow breccia in the mine is north-south with a dip of 20° to 30° east.

The Vein.—New Republic vein strikes 1° to 7° east of north and dips 54° to 65° east. On the north end of the claim the vein splits into stringers, but to the south it is well defined to a point beyond the limits of the property. The outcrop of the vein stands as the crest of the ridge on which it occurs, and at some places is four or five feet higher than its surroundings, although more frequently the cross profile of the hill is a fairly regular curve with the vein at the highest place. The outcrop is white quartz save where the extensive iron stains give a reddish brown appearance. In most places it is slightly porous, although in some it is decomposed to a mealy, chalky mass. Surface clay fills crevices in the vein material, and where mixed with the partially decomposed quartz, gives the exposure a muddy appearance. Several minor veins join the principal lead. Some of them have approximately the same strike but differ in dip, while others have the same dip but differ in strike, and still others vary by both strike and dip. With one possible exception (on the No. 4 level where the vein was badly split up) the branches extend into the foot wall, and where due to a difference in dip, always diverge toward the top, as the limb of a tree.

On No. 4 level, 100 feet north of the winze, a spur of the vein runs into the footwall with a strike of S. 15° W., and approximately the same dip as that of the main vein. A short distance below the intermediate between 3 and 4 a spur with lower dip than the main, runs into the footwall. On the second floor above the third level, the main stope has a north-south strike and dip of 62° E., while the back stope, which is in a branch of the main vein running into the footwall, strikes S. 30° W. and dips 50° E. The spur veins are always narrower than the main lode and never acquire a distance of more than 10 or 15 feet from it. As shown by a survey of the old stopes, the width of the main vein varies from 2 to 8 feet. The wider parts are great conchoidal places in the walls and seldom have a corresponding curve opposite. In several places groovings and partly preserved slicken-sides were noted.

The vein matter below the oxidized zone is a firm vitreous quartz with wavy ribbons of a bluish-gray cast closely distributed in parallel bands. Although in bold features these are parallel to the walls of the vein, in detail they are irregular, and frequently concentrically crustified. These concentric crustifications may vary from a fraction of an inch to several feet across; may be circular, elliptical, or angular, but nearly everywhere the parallel, crimpy arrangement is the striking feature. In many places angular pieces of country rock are found included in the ore, and the contact of the vein material with them, as with the walls, is always sharp. In parts of the vein where values occur and the ore is fresh, there are found intermixed with the wavy ribbons of bluish-gray cast, other ribbons of a bluish-black color and of sub-metallic to metallic luster. Such ribbons carry the values and their presence will generally serve to distinguish between barren and pay rock. This does not apply to the altered ore near the surface, for here leaching has in most instances destroyed the distinctive appearance of the ribbons.

The vein presents very few minerals. Quartz constitutes over 90% of the whole. Calcite is present, and adularia, as crystals which are usually of microscopic size, is found in considerable amounts. In the upper workings kaolin, probably carried in from the walls and also due to the alteration of adularia, is conspicuous. Chalcopyrite and pyrite are rarely seen in the mine, although in microscopic sections both appear in small quantities. Near the winze on the fourth level are small amounts of malachite and iron oxide, precipitated on the walls from the mine waters. In places gypsum is found, and occasionally little needle-like crystals of some calcium magnesium salt. The light colored bandings of the vein are due to coarser grained quartz being arranged parallel to that of finer grain, while the dark bands of metallic luster are due to the presence of some dark metallic mineral which, under the microscope, proves to be an aggregation of small crystal grains which are never of sufficient size, nor sufficiently isolated from other minerals, to afford satisfactory determination, either microscopically or chemically. From various tests made, these are thought to be a silver antimony sulphide, possibly carrying a little copper, although the copper reaction may be due to the inability to separate completely the silver antimony sulphide from the chalcopyrite known to be present in crystals of microscopic size. The presence of selenium is known and it is thought that some of the silver and all of the gold which is not free, may be associated with it. The composition of the ore is shown by the following analyses:[1]

Analyses of Ore From New Republic Mine.

CONSTITUENTS.	A.	B.	C.	D.
Silica	85.61	90.55	94.41	47.62
Alumina	6.37	4.73	2.95	9.73
Iron Oxide	3.16	2.57	1.29	(Fe) 4.94
Copper	....	....	.016	9.74
Zinc	Trace	....	.025	Not determined
Manganese	....	.20	Trace	" "
Lime	....	.90	.06	" "
Lime Carbonate	4.37	....	....	" "
Sulphur	.04	....	.06	8.23
Water	....	1.20	1.14	....
Selenium	....	....	....	5.26
Totals	99.55	100.15	99.951	....

The Ore.—The values in the ore are gold and silver. Nearly everywhere on the vein some values can be found, but the part of sufficiently high grade to constitute an ore lies in shoots

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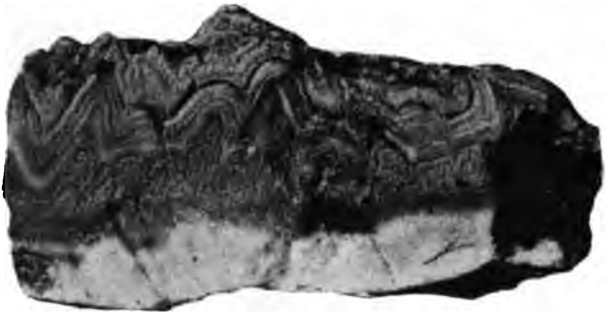
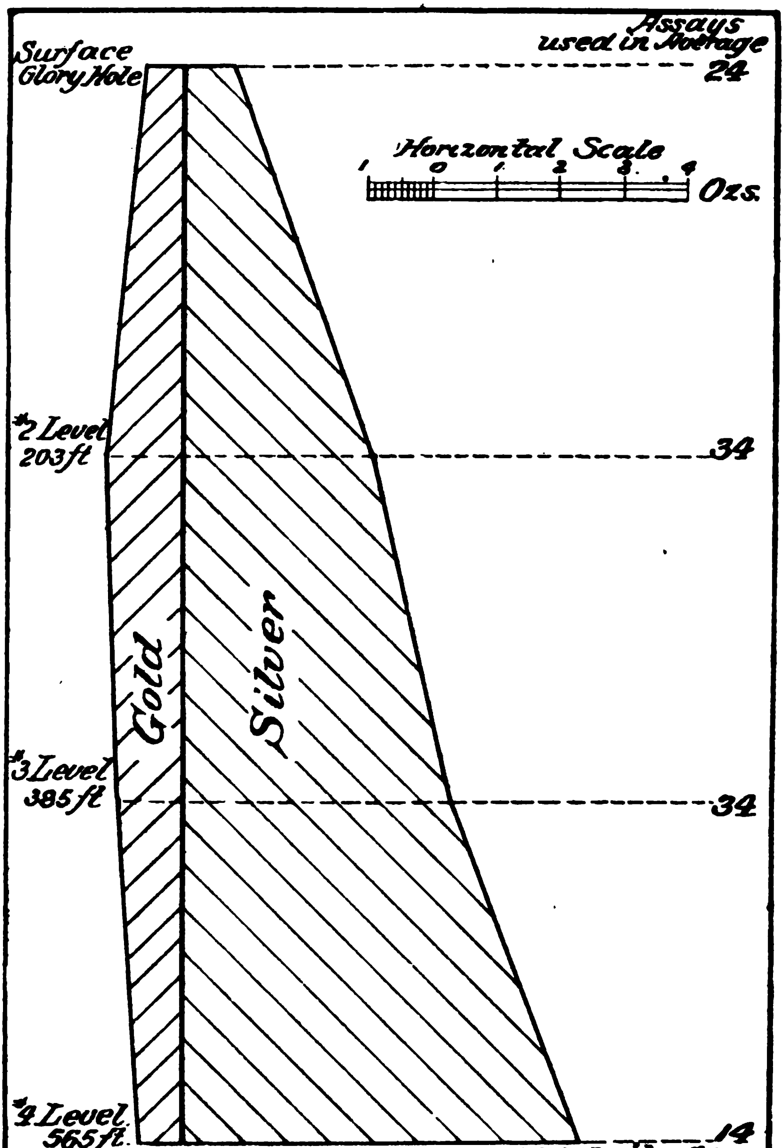
[1] A, B and C are analyses cited by Chatard and Whitehead in Trans. A. I. M. E., Vol. XXX, p. 423.

Analysis D is of selected highgrade and was made by S. G. Dewsnap, Seattle.



A—Fragment of vein showing crustification. A coarse phase. From New Republic mine. Actual size.

B—Typical appearance of Republic veins. Photo from fourth level, New Republic mine.



Wedge showing Vertical Distribution of Gold & Silver in New Republic Mine which pitch to the south. The area on the stope sheet, Plate XII, which has been mined, represents one of these shoots.

Within a shoot the ore is usually all mined, although the high grade is generally limited to kidneys, or to one or more ribbons running parallel to the walls. Rich ore occurs in the subordinate veins as well as in the main channels; indeed some of the highest grade ore taken from the property, ore said to run upwards of $40,000 to the ton, has come from one of these veins. Most of the production of 1909 came from such footwall spurs.

A noteworthy fact of the distribution of values, is the high assays which may often be secured from samples of the gossan. At a point on the vein just south of the old stope, assays of $135 were secured at the surface, and six feet below the surface a section across the vein ran 15.08 ounces in gold and 10.08 ounces in silver. With increasing depth on the vein, the ratio of silver to gold increases very markedly. The accompanying table and also Plate XI illustrate this point. The figures in the average for various levels were picked at random from assay records of the company.

Table Showing Distribution of Values in New Republic Mine.

Level.	Number of assays used in average.	Ratio in ounces of Au to Ag.
Glory Hole	25	1 : 1.09
No. 2	34	1 : 2.45
No. 3	34	1 : 4.19
No. 4	14	1 : 6.19

BEN HUR MINE

Location.—The Ben Hur mine is situated on the west side of Eureka gulch, about one mile northwest of the town limits of Republic. The property is on the northeast slope of Flag hill at an elevation of about 3,000 feet above sea level and 200 feet above the adjoining valley.

History and Production.—Development work began in 1898 and continued until 1901. Between 1901 and 1909 work was carried on intermittently. The Ben Hur Leasing Company is now operating under a lease which went into effect May 27, 1909, and between that date and September 10, 1909, put the mine in shape for operation and shipped seven cars of ore. The total production of the property is said to be about $65,000.

Development.—A tunnel near the north end of the claim cuts the vein on what is known as the 150-foot level, and by a drift of about 750 feet south on the vein connects with the shaft which extends from the surface down to a 300-foot level. Below the 150-foot level the workings were flooded at the time of the investigation. The ore recently mined came from small stopes on the 150-foot level.

Wall Rock.—The country rock is a massive latite porphyry which varies from light gray to bluish-gray in color. The rock is composed of crystals of orthoclase and plagioclase feldspar, quartz, hornblende and biotite, closely set in a crystalline groundmass. As found in the mine it is highly altered, calcite replacing the feldspars and groundmass, with chlorite in conspicuous amounts. Some sericite is formed. The biotite is bleached. Secondary pyrite is present and the presence of quartz pseudomorphic after hornblende indicates that at least some of that mineral is secondary.

The Vein.—The Ben Hur vein strikes N. 30° W. in the south part of the claim, but near the north end line turns to a position east of north. It dips 65° easterly. The vein is known to extend the full length of the claim, and as a rule varies from two feet to five feet in width.

The vein is the same in general appearance as that of the New Republic mine. In general the bands are more regular and fewer fragments of wall rock are included.

No complete analysis of the ore is available, but the terms of a contract with the British Columbia Copper Company at Greenwood, B. C., under which a penalty is required when the ore runs under 70% or over 80% silica, indicates a less siliceous gangue than in the New Republic vein. From the amount of calcite noted in the ore it is probable that the deficiency in silica as compared to the New Republic ore, is made up by an excess in lime. Out of 30 cars shipped only two were subject to penalty, and both of these ran a little over the silica limit. Commercial values are limited to shoots which, although not very well developed in the upper workings, seem to pitch uniformly to the south.

THE MORNING GLORY MINE

Location and Development.—The Morning Glory property is situated about three-fifths of a mile west, and a little south, from the Quilp mine. At the time of the investigation the workings were badly caved, so that only a very limited examination was possible. Some 1,700 feet of development work, giving a depth of over 250 feet below the surface, is reported.

Wall Rock.—The wall rock is dacite flow conglomerate and consists of a dacite matrix including numerous small waterworn pebbles of slate, quartzite, and igneous rock. It is highly altered, having a white chalky appearance due to the extensive development of calcite, with lesser amounts of sericite and occasionally adularia.[1]

The Veins.—The main vein strikes 55° east of north, and dips 60° northwest, while almost at right angles to this and dipping 85° southwest is a subordinate vein. The vein, where seen, was from 2 to 18 inches wide, and made up of a firm white quartz, banded and often drusy along the median plane. Vugs are not uncommon and these are frequently partly lined with pyrite crystals, which are always in the form of octahedrons and pyritohedrons. It is stated that the ore which has been shipped from the property carried values up to $400 per ton in gold and silver, principally gold. The total production is about $40,000.

SOUTH REPUBLIC MINE

Location.—The South Republic property is situated on the west side of Granite creek south of Republic, and near the base of the east slope of Copper mountain. It joins the New Republic claim on the southwest.

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[1] This peculiar formation is described more fully in the chapter on general geology.

History and Development.—The property was formerly known as the Princess Maude and under that name most of the development work was done. The present company was active during the summer of 1909 in installing new machinery, cleaning out the tunnel level, and unwatering the lower workings. The total development consists of a 100-foot shaft from the surface, a tunnel 488 feet long on the second level, a winze 225 feet deep from that level, and various drifts leading from it said to aggregate over 700 feet.

The Vein.—The South Republic vein strikes 5° to 10° east of north and dips about 57° east. It is inclosed in latite porphyry. The vein matter is the characteristic vitreous milky white quartz showing lines of crustification parallel to the walls. Some calcite is present as the filling of vugg-like cavities. The vein, which is inclosed between well defined walls, is regular in strike and dip, and about 3½ feet wide. At the time of the investigation the workings below the third level were under water.

THE QUILP MINE

Location.—The Quilp property is situated north of Republic, partly within the city limits, and on the east side of Eureka gulch. It is bounded on the north by the Surprise, while a break of over a mile intervenes between its southern boundary and the north line of the New Republic property.

History and Development.—This property was one of the first claims located after the reservation was thrown open to mineral entry, and was then known as the San Poil, but later relocated as the Quilp. The development consists of an adit on the 100-foot level, and a vertical shaft 400 feet deep starting from this level. Drifts extend from the shaft both north and south, on the 50-foot, 100-foot, 200-foot and 400-foot levels.[1] Exploration work and some stoping have proceeded from each of the levels, while from the 400 a winze connects with the 500, the lowest level in the mine.

---

[1] Adit level is used as datum.

Wall Rock.—The wall rock is andesite flow breccia, consisting of andesite matrix with included fragments of igneous material which are largely andesite. The lower workings were flooded at the time of the investigation, but from reports, it seems that loose gravel was encountered in the bottom of the mine. Since the wall rock of the upper workings is a flow breccia, the presence of gravels in the bottom of the mine suggests the rubble strewn surface upon which the flows were extravasated. It is not obvious that any economic significance can be attached to their presence.

The Vein.—The vein is of the type characteristic of the camp, and varies in width from 4 to 14 or more feet. The outcrop is of a reddish-brown color and stands as a bold face on the east side of Eureka gulch. The Quilp vein has been explored 600 feet on the dip, and continues north as the Surprise vein, while to the south it has not been identified.

The Ore.—The ore occurs in a shoot which pitches 50° to 60° south. Values are in gold and silver in the average ratio by ounces of 1 of gold to 9.1 of silver. Above the 100-foot level gold was to silver as 1 to 12.19, while at greater depth the ratio was as 1 to 6.08. It will be noted that this is the reverse of the rule for the camp, for in all other mines where data were available, the ratio by ounces of gold to silver decreases with depth. (See Plate XI and Fig. 5). The incongruity may possibly be explained by a local secondary concentration of silver in the upper levels. It is also noteworthy that assays running as high as $300 have been secured from the very grass roots.

The total ore shipped aggregates 24,000 tons with a value of about $275,000. The company estimates 80,000 tons of ore in sight.

THE SURPRISE MINE

Location.—The Surprise mine is situated on the east side of Eureka gulch, and lies between the Blacktail property on the north and the Quilp on the south.

History and Production.—The claim was among the first to be located in the camp and during the early days of activity was extensively prospected but never mined. Early in the spring of 1909 D. H. Wells and associates secured a six months lease providing for a 25% royalty, on 100 feet of the vein. An upraise was immediately started from the 100-foot or tunnel level and after raising through some 20 feet of low grade quartz the ore body was found. The total production of the mine is about 2,400 tons, with an average value of approximately $21.65 per ton, all of which came from the upper 85 feet of a section of the vein 100 feet long.[1] The property is one of the Lone Pine-Surprise group of claims, which recently passed into the hands of the Republic Mines Corporation.

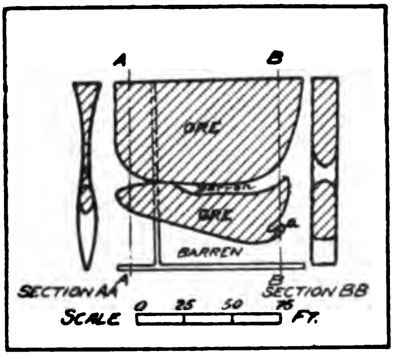


Fig. 2. Surprise stope and cross section of vein showing distribution of ore.

The Vein.—The Surprise vein, which is included in andesite flow breccia, strikes north 30° west and dips 70° east. Along the strike it can be readily traced onto the adjoining properties both north and south. The fresh vein matter is firm quartz of bluish color, showing the characteristic ribbon-like banding of darker material, with here and there cubes of iron pyrite. The upper 30 to 60 feet of the vein is oxidized to a reddish color.

---

[1] It is reported that a shoot of ore some 400 feet long and giving assays which range up to $700 per ton has been recently discovered just north of the one above described.

The walls are approximately parallel and faced by countless small angular irregularities. The contact of wall rock and ore is clean cut, however, so that in mining the ore is readily stripped.

The Ore.—The ore occurs in shoots which, as far as the limited development indicates, pitch toward the south. The stope sheet (Fig. 2) of the 100 feet worked by the leasers shows the distribution of the ore in the only part of the vein which is well known. In places along the vein the ore grades out into lean quartz, but in others it is sharply cut off by fragmental wall material which completely fills the fissure. The writer visited the point "a," Fig. 2, just before the noon blast and found a face of good ore. After the blast a clean face of brecciated country rock was found. There was no evidence of faulting and it seemed probable that the fissure at this point had been filled by wall fragments before the metal-bearing solutions entered.

THE BLACK TAIL MINE

Location and Development.—The Black Tail property is located on the east side of Eureka gulch, between the Surprise property on the south and the Lone Pine on the north. The development consists of about 2,000 feet of horizontal and vertical workings. Not much stoping has been done, but several carloads of ore have been shipped from above the first level.

The Veins.—Three distinct veins (see Fig. 3) are found on the Black Tail property, all of which are included in andesite flow breccia. The main tunnel, which enters the hill about 30 feet above the level of Eureka creek, cuts the No. 1, or Surprise vein, 80 feet from the portal. The vein is somewhat indefinite at this place, but is apparently about 4 feet wide, and strikes N. 40° W., dipping 75° east. It has been mined to a limited extent farther north on the Black Tail property, where a shoot of medium grade ore about 65 feet long and pitching 20° to the south, was found. About 300 feet east of the No. 1 is No. 2, or Black Tail vein. North of the center of the claim it has essentially the same strike as No. 1 vein, but differs from that

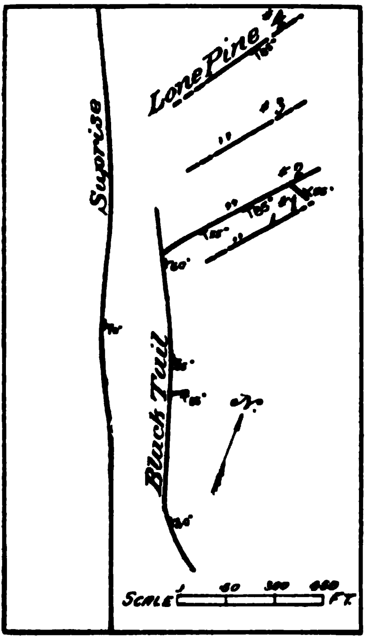
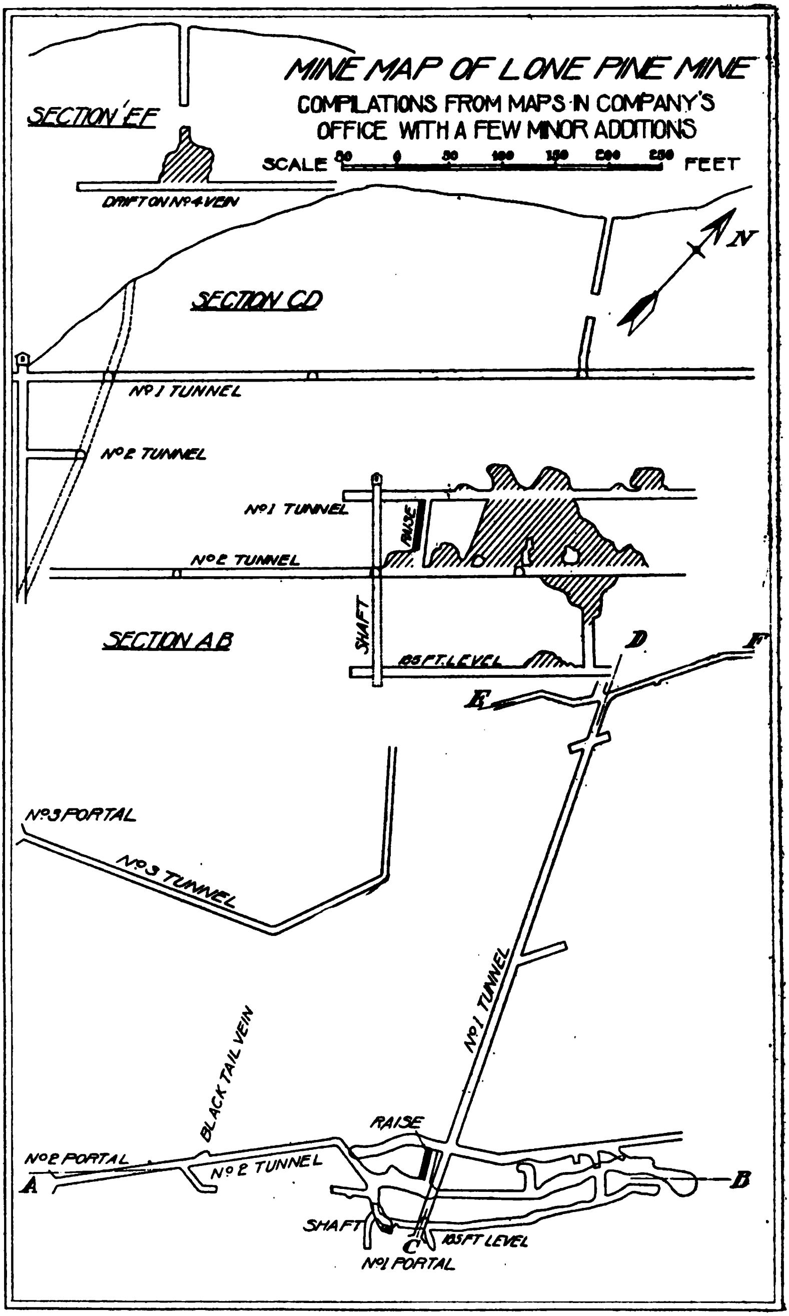


Fig. 3. Pattern of veins on Lone Pine and Black Tail claims.

vein in having a dip of only 46° east. South of the center of the claim the vein turns to a direction 45° west of south and flattens to a dip of 40°. It is near this bend in the vein that most of the ore has been found. South of the bend the vein can be traced for a short distance, but not beyond the limits of the claim. No. 2 vein is irregular in width and in values, especially on the second level. The walls are slickened and frequently show distinct groovings, which, when measured, are found to incline about 15° south. While the movements making the slickensides are thought to be pre-mineral, yet post-mineral movements are evidenced by a slight brecciation in parts of the vein. Vein No. 3, which has not produced any ore, outcrops near the north end of the property, and east of the No. 2 vein. It strikes north 48° east and dips 85° southeast, thus placing it almost at right angles to the other veins. Eastward its outcrop is concealed by drift, while to the west it does not appear to cross No. 2 vein. The three veins are believed to be essentially contemporaneous in origin.


MINE MAP OF LONE PINE MINE
COMPILATIONS FROM MAPS IN COMPANY'S OFFICE WITH A FEW MINOR ADDITIONS
SCALE 50 0 50 100 150 200 250 FEET
N
SECTION EF
DRIFT ON NO 4 VEIN
SECTION CD
NO 1 TUNNEL
NO 2 TUNNEL
NO 1 TUNNEL
RAISE
NO 2 TUNNEL
SHAFT
SECTION AB
185 FT. LEVEL
D
F
E
NO 3 PORTAL
NO 3 TUNNEL
NO 1 TUNNEL
BLACK TAIL VEIN
RAISE
NO 2 PORTAL
A
NO 2 TUNNEL
B
SHAFT
C
185 FT LEVEL
NO 1 PORTAL

LONE PINE MINE

Location.—The Lone Pine mine is situated on the east side of Eureka gulch about three-quarters of a mile north of Republic. It is bounded on the south by the Black Tail, on the north by the Little Cove, on the west by the Pearl, which is a part of the same property and included in this discussion, and on the east by the Insurgent fraction, which has been largely worked through the Lone Pine tunnels.

History and Production.—The Lone Pine was located in March, 1896, being one of the first claims staked in the camp. It is the principal claim of the Lone Pine-Surprise group, and for several years was owned by the Pearl Consolidated Mining Company. Recently, however, the Lone Pine-Surprise group of claims was purchased by the Republic Mines Corporation, who are now actively operating the properties.

The total production of the property is about 8,600 tons, carrying in round figures $119,000 in gold and $18,000 in silver. Except for a small amount of ore which was handled by the old Republic Power and Cyaniding Mill, the output has been shipped to British Columbia and Washington smelters.

Development.—The property has been explored by over three thousand feet of tunnels, shafts and drifts. The No. 1, or principal development tunnel, approximately follows the lode line of the claim for 700 feet, roughly paralleling one system of veins and cutting four veins of another system. Drifts have been run both ways on three of the veins crossed. The first vein appears under shallow cover near the portal, but has not been explored. No. 2 tunnel enters the hill from a point near the junction of a tributary with Eureka creek and gives 72 feet additional depth. The lowest level is 95 feet below No. 2, or 185 feet below the surface, and is reached by a double compartment shaft located near the portal of No. 1 tunnel. No. 3, or Pearl tunnel, enters the hill from a point on the Pearl claim near the level of Eureka creek and cuts the most northerly of the four veins found in No. 1. These relations will be readily seen by reference to Fig. 3.

The Veins.—There are seven veins on this property (Lone Pine and Pearl claims) and all are enclosed in andesite flow breccia of the usual type. The Black Tail and Surprise veins, which continue here, strike 20° to 30° west of north and dip east. The Lone Pine Nos. 1, 2, 3, and 4 strike from 33° to 42° east of north and dip south. Not one of the latter veins have been found west of the Black Tail vein. The Lone Pine No. 2 in turn cuts off a vein which strikes 60° west of north and dips east (see Fig. 3). Thus there is a northwest-southeast vein cut off by a northeast-southwest vein and this in turn cut off by a northwest-southeast vein. In no case has a continuation of a vein been found beyond the vein which crosses its course. The several veins will be separately considered.

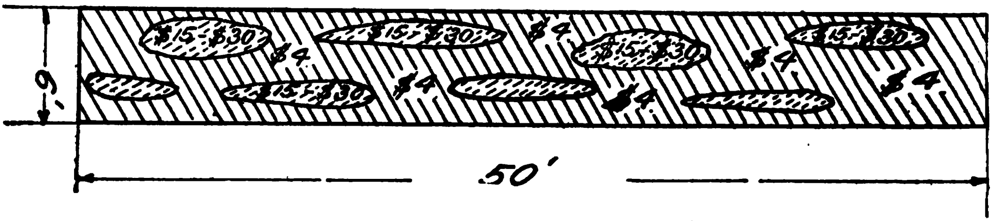


Fig. 4. Diagram showing occurrence of ore in lenses in Lone Pine No. 2 vein.

The Surprise vein, as found on this property, strikes north 20° west and dips 70° east. The outcrops are along the base of the valley side, and, although uncovered by several prospect pits and short tunnels, no shipments have been made, although the same lead has been mined on the Little Cove property to the north, and on the Black Tail to the south. The vein varies between four and eleven feet in width, and is composed of a firm bluish quartz showing the characteristic ribbon-like banding of darker material. As seen on this property it is usually oxidized to a reddish-brown color.

The Black Tail vein is exposed south of the draw which crosses the south end of the property, and also at a point 130 feet from the portal in the No. 2 tunnel, but does not appear in the No. 3 tunnel. The Black Tail and Surprise vein is about five feet wide on the north side of the tunnel, but on the south side it is a gouge seam 8 to 16 inches wide with about 2 feet of badly disturbed ground on either side. Grooves on the hanging wall incline 15° to the south. The southward extension of the vein is readily traced into the Black Tail property, but north of the exposure in No. 2 adit it has not been identified.

No. 1 Lone Pine vein, which is five feet wide, strikes N. 40° E. and dips southeast. It does not appear in No. 2 tunnel, and is thought to be cut off by the Black Tail lead.

No. 2 vein lies about 100 feet north of No. 1 and is essentially parallel to it. It dips 85° southeast. No. 2 adit, running N. 20° E., crosses the Black Tail vein 130 feet from the portal, which is about 15 feet beyond the normal position of No. 2 Lone Pine vein. The tunnel extends ahead from this point about 100 feet, then makes a right angle turn to the southeast, and crosses the No. 2 vein in a short distance. Stated otherwise, the No. 2 vein does not appear west of the Black Tail lode, but east of that vein it is found.

No. 2 has been traced from its junction with the Black Tail to a point well beyond the east limits of the claim, and explored along its dip to a depth of about 300 feet. On the Lone Pine property the vein varies from 4 to 14 feet in width, but beyond a point about 100 feet east of the boundary of the claim, it is poorly defined. In the old stopes horses up to 15 or 20 feet in length are found in many places. The unaltered vein material is firm vitreous quartz of bluish cast, carrying from 6% to 9% of calcite, usually in the form of small vug fillings, but sometimes as crustifications interbanded with quartz. The banding is similar to that occuring elsewhere in the camp, the bolder features being due to alternating layers of different shades of quartz, while the minor bands have a sub-metallic luster and are more crimpy and closely spaced. The bands of sub-metallic luster carry the values. In the upper workings the ore is largely altered to a light buff chalk-like material, which is slightly friable on exposure.

The values are in gold and silver in the proportion of about $6.75 in gold to $1.00 in silver. The distribution in ounces is 1 of gold to 5.75 of silver above the No. 2 level, and 1 of gold to 8.59 of silver below that level. These relations are shown diagrammatically in Fig. 5. The ore occurs in lenses which in the upper workings ran $15 to $30 per ton, while the intermediate vein material carries about $4 values. (See Fig. 4.)

No. 3 vein has been explored for a short distance, but has never been worked. It is a quartz vein similar in strike and dip to Nos. 1 and 2, but is not considered commercial ore under existing conditions.

Vein No. 4 is approximately parallel to No. 2 and lies about 400 feet south of it. It is intersected by No. 1 and No. 3 tunnels. From the No. 1 tunnel a little over 700 tons of ore with an average value of about $15 per ton has been shipped. The ratio in ounces was 1 of gold to 3.82 of silver.

The north-south vein which is cut off by No. 2 vein is about four feet wide and dips 50° east. The vein matter is a typical quartz breccia, firmly cemented by dark siliceous material with frequent films and irregular patches of pyrite scattered through (Plate VI). Values in the vein run from $4 to $5, but at the contact with the No. 2 vein ore running as high as $157 was found. The brecciated appearance of this vein, in contrast to the firm nature of the No. 2 vein which it abuts, suggests an earlier and later period of mineralization. As discussed in the section on genesis, this contrast in the physical character of the veins is, however, thought to be only indicative of stages in a somewhat broken period of mineralization.

SAN POIL PROPERTY

Location and Development.—The San Poil claim is situated on the west side of Eureka gulch almost opposite the Lone Pine, and south of the Ben Hur. The property has been developed by some 2,500 feet of tunnels and drifts which explore the vein for about 1,000 feet along the strike and for 300 feet on the dip. Little stoping has been done.

The Vein.—The vein, which is enclosed in latite porphyry, extends throughout the entire length of the claim, and has the banded vitreous appearance characteristic of the entire camp.

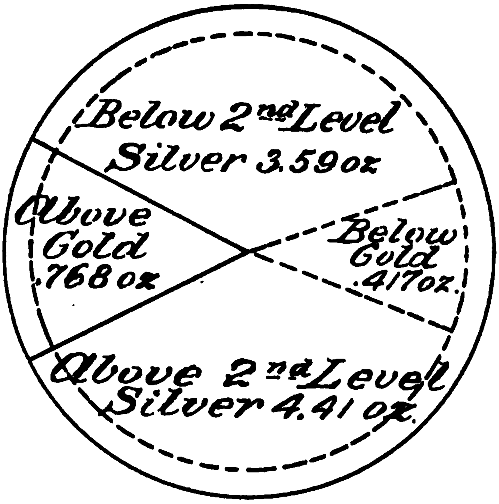


Fig. 5. Diagram showing variation in vertical distribution of gold and silver in Lone Pine mine. The solid lines apply to values, above No. 2 level, and the dotted lines to values below No. 2 level. Wedges show relation of gold to silver in each. Diagram based on average values in ounces per ton.

It is the southward extension of the Ben Hur vein, but has not proved as productive as on that property.

MOUNTAIN LION MINE

Location.—The Mountain Lion mine is situated about three miles north-northwest of the city limits of Republic, and on the east side of the north fork of Granite creek. Although north of the end of Eureka gulch, the veins are in essential alignment with the leads there found.

History and Development.—The Mountain Lion, which is the principal claim of the Mountain Lion group, was located March 20, 1896. Two years after the location the owners incorporated under the name Mountain Lion Gold Mining Company, and began extensive development work early the following year. A tunnel starts from a point near the level of North fork and cuts the vein 1,260 feet from the portal, giving a depth on the vein of 310 feet. A double compartment vertical shaft, which passes near the inner end of the tunnel, reaches a depth of about

700 feet from the surface. Drifts and crosscuts leave the shaft at several levels.

The total production of the mine is not known, but it is generally reported to be about $200,000. The ore largely came from stopes above the tunnel level.

Wall Rock.—The wall rock is andesite flow breccia. As elsewhere, it has an andesite matrix with included fragments largely andesite. It is always highly altered to a whitish color, due to the decomposition of the feldspars and the development of calcite and sericite and, near the vein, to the introduction of silica.

Veins.—There are three almost parallel veins on the property, but only one of them carries sufficient values to be considered commercial under existing conditions. The productive vein has been traced for more than 800 feet along the strike and to about the same distance on the dip. It strikes nearly north and south and dips 60°-70° west, being the only westward dipping vein in the camp. The vein material is similar to that found in all the other productive veins of the area.

TOM THUMB MINE

Location and Development.—The Tom Thumb is the most northerly mine in the district, and is situated near the headwaters of the North fork of Granite creek, three and one-half miles north of the city limits of Republic. The croppings are on a bench a quarter of a mile back from North fork and at an elevation 200 feet higher.

The development consists of three shafts, and drifts and crosscuts from them, aggregating in all some 1,600 feet of exploitation work. The working shaft has two compartments and is so situated that it intersects the vein 365 feet below the collar. For several years the mine was idle, but early in the fall of 1909 it was leased by the New Republic Mining Company, and is now shipping about 25 tons per day. The values are said to run from $12 to $14 per ton.

Wall Rock.—The wall rock, as seen from the surface,[1] is andesite flow breccia, although a latite porphyry lies a short distance to the west. Immediately overlying the andesite breccia is a series of tufaceous lake beds, which outcrop along the Great Northern railroad tracks between No. 2 and No. 3 shafts. The series strikes parallel to the veins and dips in the same direction, but at a much lower angle. Intruded into both the flows and the tuffs is igneous material which, since it was found at one place on the Tom Thumb claim to include vein quartz, is younger than the veins.

The Veins.—The veins are a complex system striking 30° to 45° east of north and dipping 35° to 40° southeast. The main vein is about nine feet wide and outcrops along the lode line of the Plug Hat claim, which lies just east of the Tom Thumb claim and is a part of the same group. The vein is traceable only for about one-third of the length of this claim, but to the west a similar vein extends about three-fourths the length of the Tom Thumb claim. These may be the same vein offset with overlap, but the evidence is not sufficient to warrant a definite statement. A number of small veins which seldom continue for over 50 feet along the strike lie parallel to the main vein, which is itself very variable in width.

The outcrops of the veins are usually milky-white quartz devoid of metallic minerals, but in places a heavy iron stain suggests their former presence.

THE ELCALIPH MINE

The Elcaliph property lies just east of the Morning Glory, and the vein is similar in all characteristics noted to the Morning Glory vein. It was possible to visit the surface workings only.

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[1] At the time of the investigation the mine had not been unwatered, so that the following observations are all made from the surface.

INDEX

Page

- Acknowledgments ... 7
- Adularia ... 40
- Andesite Flows and Lake Beds ... 23
- Andesite Flow Breccia, Earlier ... 28
  - Age ... 24
  - Characteristics ... 23
  - Distribution ... 23
- Andesite Flows, Later ... 25
  - Characteristics ... 26
  - Distribution ... 25
- Basalt Flow ... 28
  - Characteristics ... 28
  - Relations ... 28
- Ben Hur Mine ... 50
  - Development ... 51
  - History and Production ... 50
  - Location ... 50
  - Wall Rock ... 51
  - Vein, The ... 51
- Black Tail Mine ... 56
  - Location and Development ... 56
  - Veins, The ... 56
- Calcite ... 40
- Chalcopyrite ... 40
- Changes in Drainage ... 10
- Climate ... 14
- Correlation of Eocene Peneplain ... 12
- Dacite Flow Conglomerate ... 20
  - Age ... 22
  - Characteristics ... 21
  - Distribution ... 20
- Drainage, Present ... 9
- Drainage, Former ... 10
- Drift, The ... 29
- Elcaliph Mine ... 65
- Eocene Peneplain ... 11
  - Correlation ... 12
- Erosion, Stream ... 80
- Eureka Mining District ... 7
- Field-work ... 7
- Genesis of the Ore ... 41
- Geology, General ... 15
- Glaciation ... 29
- Glacial Features ... 10
- Gold ... 40
- Granodiorite ... 17
  - Age ... 18
  - Characteristics ... 18
  - Distribution ... 17
- Gypsum ... 40
- Iron Oxide ... 40
- Lake Beds ... 24
  - Age ... 24
  - Characteristics ... 24
  - Distribution ... 24
- Latite Porphyry ... 27
  - Characteristics ... 27
  - Distribution ... 27
- Lone Pine Mine ... 59
  - Development ... 59
  - History and Production ... 59
  - Location ... 59
  - Veins, The ... 60
- Malachite ... 40
- Metallurgy ... 84
- Minerals of the Ore ... 39
- Mining Development, History of ... 32
- Moraines ... 29

Page

- Morning Glory Mine ... 52
  - Location and Development ... 52
  - Veins, The ... 52
  - Wall Rock ... 52
- Mountain Lion Mine ... 63
  - History and Development ... 63
  - Location ... 63
  - Veins ... 64
  - Wall Rock ... 64
- New Republic Mine ... 44
  - Analyses of Ore ... 48
  - Development ... 45
  - History and Production ... 44
  - Location ... 44
  - Ore, The ... 48
  - Vein, The ... 46
  - Wall Rock ... 45
- Ore, Minerals of the ... 39
  - Analyses of high grade ... 39
  - Genesis of the ... 41
- Paleozoic Series ... 16
  - Age ... 17
  - Characteristics ... 16
  - Distribution ... 16
- Peneplain, Eocene ... 11
- Placer Mining ... 43
- Previous Work ... 8
- Production ... 84
- Pyrite ... 40
- Quartz ... 41
- Quaternary History ... 28
- Quilp Mine ... 53
  - History and Development ... 53
  - Location ... 53
  - Ore, The ... 54
  - Vein, The ... 54
  - Wall Rock ... 54
- Rainfall ... 8, 14
- Remarks, General ... 8
- Republic Mine (see New Republic Mine)
- Republic Mining District ... 7
- San Poil Property ... 62
  - Location and Development ... 62
  - Vein, The ... 62
- Silver ... 41
- South Republic Mine ... 52
  - History and Development ... 53
  - Location ... 52
  - Vein, The ... 53
- Stream Erosion ... 30
- Stromme, Olaf, work of ... 7
- Surprise Mine ... 54
  - History and Production ... 55
  - Location ... 54
  - Ore, The ... 56
  - Vein, The ... 55
- Tertiary Formations ... 19
  - Relation to Older Formations ... 19
- Tom Thumb Mine ... 64
  - Location and Development ... 64
  - Veins, The ... 65
  - Wall Rock ... 65
- Topography ... 9
- Trachyte Flow ... 25
- Veins, The ... 37
  - Characteristics ... 87
  - Distribution ... 87
  - Geologic Relations of ... 41
- Weather Conditions at Republic ... 14

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HENRY LANDES, State Geologist

BULLETIN No. 2

The Road Materials
OF
WASHINGTON

By HENRY LANDES

Assisted by Olaf Stromme and Clyde Grainger

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LETTER OF TRANSMITTAL.

Governor M. E. Hay, Chairman, and Members of the Board of Geological Survey:

Gentlemen—I have the honor to submit herewith a report entitled "The Road Materials of Washington," with the recommendation that it be printed as Bulletin No. 2 of the Survey Reports.

Very respectfully,

HENRY LANDES,

State Geologist.

University Station, Seattle, March 1, 1911.

CONTENTS

Page

ILLUSTRATIONS 7

INTRODUCTION 9

CHAPTER I. The varieties of rocks tested for use as road materials, with their general distribution 13
  Igneous rocks 13
  Sedimentary rocks 21
  Metamorphic rocks 23

CHAPTER II. Methods of testing road materials, with the results of the tests made upon Washington rocks 27
  Examination of rock in the ledge 27
  Practical use of the rock 29
  Laboratory tests upon selected samples 30
  Table A. Maximum and minimum results of tests of rock samples, taken from all parts of the United States 33
  Table B. Results of tests made upon certain road materials of Washington 34

CHAPTER III. The distribution of road materials within the state, by counties 40
  Adams 40
  Asotin 43
  Benton 47
  Chehalis 51
  Chelan 55
  Clallam 59
  Clarke 60
  Columbia 63
  Cowlitz 66
  Douglas 74
  Ferry 77
  Franklin 85
  Garfield 88
  Grant 90
  Island 95
  Jefferson 95
  King 99
  Kitsap 106
  Kittitas 108
  Klickitat 113
  Lewis 117

CHAPTER III. **Distribution of Road Materials**—*Continued:* *Page*
Lincoln 121
Mason 128
Okanogan 131
Pacific 134
Pierce 140
San Juan 144
Skagit 148
Skamania 154
Snohomish 157
Spokane 162
Stevens 168
Thurston 178
Wahkiakum 182
Walla Walla 186
Whatcom 191
Whitman 195
Yakima 199

ILLUSTRATIONS

Plates *Facing Page*
I. Map of Washington 40
II. Southern part of Chehalis county 53
III. Parts of Ferry county 79
IV. East central part of Grant county 90
V. Northern part of King county 100
VI. Part of Kittitas county, near Ellensburg 108
VII. Central part of Klickitat county 115
VIII. Eastern part of Lincoln county 123
IX. Western part of Pacific county 134
X. Western part of Skagit county 148
XI. Western end of Snohomish county 159
XII. Central part of Spokane county 162
XIII. Stevens county: Along the Colville valley from Loon Lake to Arden 168
XIV. Stevens county: Along the Columbia and lower Colville valleys 170
XV. Stevens county: Parts of the Pend Oreille valley 172
XVI. Southwestern part of Walla Walla county 186
XVII. Northern part of Whitman county 196
Figures *Page*
1. Central part of Adams county 41
2. Position of basalt quarry near Lind 42
3. Eastern part of Asotin county 44
4. Basalt quarry near Asotin 46
5. Rogers mountain, near Zindel 47
6. Central part of Benton county 48
7. Location of basalt quarry, near Hoquiam 54
8. East central part of Chelan county 56
9. Southwestern part of Clarke county 60
10. Basalt quarries near Fisher 62
11. Northern part of Columbia county 64
12. Southwestern part of Cowlitz county 66
13. A—Basalt quarries near Stella. B—Quarry and crusher at Ladu 72
14. Southern end of Douglas county 74
15. A—Basalt ledges near Vulcan. B—Cliffs near Columbia River Station 76
16. Basalt outcrop near Republic 79
17. Southeastern part of Franklin county 85
18. Basalt cliff near Kahlotus 87
19. Northern part of Garfield county 89
20. Southeastern part of Jefferson county 96

Figures *Page*
21. A—Basalt outcrops north of Port Ludlow. B—Basalt ledges south of Brinnon.............................. 97
22. A—County quarry one mile south of Snoqualmie. B—Basalt quarry and crushing plant between Riverton and Duwamish 101
23. A—Granite quarry at Halford. B—Quarry of Seattle Park Board, near Franklin.............................. 104
24. Central part of Kitsap county.............................. 106
25. Quarry 2½ miles south of Charleston.............................. 108
26. A—Basalt quarry near Umptanum. B—Basalt cliffs near Kountze 112
27. Northwestern part of Lewis county.............................. 118
28. State quarry and crushing plant at Meskill.............................. 120
29. Part of Lincoln county, around Wilbur.............................. 123
30. A—Some basalt ledges at Wilbur. B—Basalt cliffs near Sprague 126
31. North central part of Mason county.............................. 129
32. North central part of Okanogan county.............................. 131
33. Location of the basalt quarry near South Bend.............................. 136
34. South central part of Pierce county.............................. 140
35. Map of San Juan county.............................. 145
36. Fidalgo Island and state quarry.............................. 150
37. A—Some quarries and crushing plants near Burlington. B—Plan of quarry and crushing plant at state quarry on Deception Pass 151
38. Southern part of Skamania county.............................. 155
39. Basalt cliffs near Cape Horn.............................. 156
40. Rock outcrops and quarries at Granite Falls.............................. 160
41. Plan of state quarry and crushing plant at Marshall.............................. 165
42. A—Ledge of basalt at Springdale. B—Deposit of volcanic ash at Meyer's Falls.............................. 175
43. Western part of Thurston county.............................. 179
44. A—Basalt quarry west of Olympia, on Mud Bay. B—Ledge of rock three miles northeast of Gate.............................. 181
45. Map of Wahkiakum county.............................. 183
46. Basalt ledges near Skamokawa.............................. 185
47. A—Outcrops of basalt in the vicinity of Lamar. B—State quarry at Dixie.............................. 189
48. Western part of Whatcom county.............................. 191
49. A—Basalt quarry near Pullman. B—Outcrops of basalt at Rosalia 197
50. Part of Yakima county, near North Yakima.............................. 200
51. Plan of the Selah state quarry and crushing plant, near North Yakima 201

INTRODUCTION.

The Legislature at the session of 1909 passed an act providing for an examination of the road materials of the state, under the direction of the Board of Geological Survey. (Chapter 226, Session Laws, 1909). It was stipulated in this law that a field examination should be made of the rock deposits conveniently located for transportation, and which might yield materials suitable for road building. It was further directed that samples of such rocks should be tested in the laboratory, and that the results of the field-work and laboratory tests should be set forth in proper maps and printed reports. Besides a general survey it was specifically provided that a number of desirable rock deposits should be selected, both east and west of the Cascade mountains, where the state might own and operate quarries and crushing plants.

The work of preparing a report upon the rock materials was placed by the Board of Geological Survey in the hands of the State Geologist. He was assisted in the field by Olaf Stromme and Clyde Grainger. The samples that were collected from the ledges of rock examined were sent to Washington, D. C., where they were tested in the laboratory of the Office of Public Roads, United States Department of Agriculture. The results of the tests made upon 171 samples of rock are given in later pages of this report.

In the work of the road material survey the first task undertaken was the selection of the state quarry sites. Many localities were examined before the final selections were made. In determining the proper locations for these quarries the chief considerations were the quality and quantity of the rock deposits, their positions as regards easy transportation, and the local demands or uses for the crushed rock. Quarry sites were finally chosen at two points west of the Cascade mountains, viz., at the south end of Fidalgo Island, on Deception Pass, in Skagit county, and at Meskill, a few miles west of Chehalis, in Lewis county. At the former place a high cliff of rock rises directly from the edge of the Sound, affording transportation by water. The material is a feldspathic sandstone of good quality for road building. At Meskill the rock is a basalt which has been used for some years in road building and its good qualities determined by practical use.

On the east side of the Cascade mountains three sites were selected as follows: At Selah Gap, two miles north of North Yakima, in Yakima county; at Marshall, a few miles southwest of Spokane, in Spokane county; and at Dixie, 11 miles northeast of Walla Walla, in Walla Walla county. At all of these places basalt of good quality occurs in sufficient quantities to supply large crushing plants for a great many years. In each instance a railway line passes directly by the quarry, thus making the shipping problem an easy one.

In making a general survey of the state for deposits of road materials it was the policy not to depart very far from the lines of easy transportation. Nearly every mile of railway in the state was covered, usually on foot, and the various outcrops of rock along the way noted. Where such deposits seemed to be of value for road building, both as to quantity and quality, thirty-pound samples were taken at each locality to be further tested in the laboratory. In a similar way the shores of all navigable water bodies were explored in the search for road materials, and samples taken from all the larger ledges that are conveniently located for the establishment of quarries and the easy shipment of crushed rock. About the cities and towns the country roads were followed for some miles in an effort to locate any desirable deposits that might yield crushed rock for street or highway use.

This report is intended to be a preliminary one only upon the road materials of the state. Samples were not collected to be tested except where it would be entirely possible to develop a quarry and establish a crushing plant, and where the shipping problems could be readily solved. Furthermore the principal work in the examination of road materials was done where the highways of the state will have their most rapid development and where the demands for the proper materials for macadam roads must first be met. It will be recognized, of course, that there are very many other rock deposits within the confines of Washington that would yield just as good road materials as those mentioned later in these pages, but that the scope of this survey was not broad enough to include them. It will remain for future surveys to explore the less known or less developed portions of the state and thus complete our knowledge of one of the most valuable mineral resources of the commonwealth.

THE ROAD MATERIALS OF WASHINGTON.

CHAPTER I.

THE VARIETIES OF ROCKS TESTED FOR USE AS ROAD MATERIALS, WITH THEIR GENERAL DISTRIBUTION.

The State of Washington is unique in the great variety of rocks which occur within its borders. All the common rocks are found in large quantities, and many unusual ones have been discovered. The large number of outcrops of bed-rock is unique as well. Within the mountains, among the hills, and along nearly all the streams the underlying rock projects with great frequency through the overlying mantle of broken rock and soil. In some localities, usually in the lowlands, or over the broad plains, a number of square miles of country may be so deeply soil covered that the bed-rock is effectually hidden. Such instances as these are the exception and not the rule. A classification of the kinds of rock examined and tested may be made as follows:

Igneous Rocks.

Andesite
Basalt
Diabase
Diorite
Gabbro
Granite
Granodiorite
Rhyolite
Syenite
Volcanic ash

Sedimentary Rocks.

Limestone
Sandstone

Metamorphic Rocks.

Gneiss
Marble
Quartzite
Schist
Serpentine
Slate

IGNEOUS ROCKS.

ANDESITE.

This variety represents a rock which has usually come to the surface of the earth in a molten state, either through volcanic vents or through fissures. Sometimes it occurs as dikes which have been intruded into the overlying rock. It is the prevailing rock which makes up the large volcanic cones of the state. It takes its name from the Andes mountains, where it was early found and described. It is usually a gray or green rock, almost always mottled in appearance. It possesses a very fine grained ground mass, in which there are commonly small crystals of feldspar, with smaller amounts of hornblende, augite, and biotite. As a general thing it is a compact rock with a small amount only of pore space.

Andesite is a rock of moderate hardness and toughness, with good wearing qualities. As a rule it possesses a high cementing value so that it binds well in a highway. It is of more durability when it is fine grained than when coarse grained, especially when care is taken to select rock only that is compact and free from pores, and that is fresh and unweathered.

This rock was tested at eighteen localities in the state, mainly in Ferry, King, Pierce, and Snohomish counties. It is of widespread occurrence, the larger areas being in the high mountains. In the lowlands it is found very frequently where it has been thrust into fissures in the stratified rock, or where it has reached the surface and outflowed until it congealed. It is often found in small low hills or ridges. Sometimes the overburden is so great that the rock can not be economically quarried. It is one of the valuable rocks of the state as a source of road material, and all occurrences of it should be mapped and described.

BASALT.

Basalt represents a basic variety of the igneous rocks. It has a higher specific gravity than most rocks, and a color varying from dark gray to black. As a rule it is very fine grained, with the crystals too small to be seen with the naked eye. Occasionally it becomes more coarsely crystalline and grades into basalt porphyry or dolerite. The fracture is almost always conchoidal or shell-like, and the broken fragments have sharp edges. The rock is often very porous due to the presence of steam holes. In the process of cooling the steam has been under such high pressure that it has formed bubbles about which the rock has solidified. The pores so formed vary in size from microscopic to several inches in diameter. They may occur in such abundance that the rock is really pumice in character. Basalt, when very fine grained and compact, is a very durable rock and is very slowly acted upon by the weathering elements.

Basalt is generally regarded as the best kind of rock for use as a road material. Care must always be exercised in selecting basalt that is fine grained, most compact, and least weathered. It is a hard and tough rock, with high specific gravity, and offers strong resistance to wear. As a rule its cementing value increases as its hardness and toughness decrease. Some basalts are so very hard and tough that they do not abrade under the impact of hoofs and wheels and hence yield too little dust to serve as a cement in binding the larger fragments together. Such rocks should be used only on roads where there is the heaviest traffic. For roads of moderate traffic basalt should be selected of lower hardness and toughness so that the cementing power will be high enough to insure the roadway from breaking up and failing to cement properly.

For this report samples of basalt were selected from 95 localities. It is the most common variety of rock in the state. It is most abundant in southeastern Washington where it is part of a great lava plain, covering over 200,000 square miles, which extends across Idaho and Oregon into California. The rock occurs here as broad sheets of overlapping lava. The basalt has come to the surface in a molten condition and has flowed far away from the fissures before it solidified. In some of the great cliffs along Columbia and Snake rivers the edges of several individual flows may be seen. The total thickness of basalt varies from 2,000 to 4,000 feet. A great deal of the rock is very porous, especially in those portions near the upper surface of each layer. The middle and lower parts of a layer or flow are generally dense and rather free from pores, and capable of yielding excellent material for road use.

Basalt is found in abundance in other parts of the state, sometimes as dikes and at other times as sheets or flows where it has welled out of fissures. Outside of the great lava plain it is characterized by a very large number of occurrences rather than by an unusual amount in any one place. As a rule the rock is of better quality where it is in the form of dikes than where it occurs as flows or sheets. Good deposits of basalt occur very convenient to transportation, as along Columbia river and on the shores of Puget Sound. Deposits have been found along practically all of the railway lines so that it may be distributed for road building almost anywhere in the state.

DIABASE.

The minerals in this rock are mainly plagioclase feldspar, augite and olivine, with more or less magnetite. The feldspar crystals are usually long and slender or lath-shaped. The other minerals are in small irregular masses among the interlacing rods of feldspar. The mineral composition is essentially the same as in the basalt. The chief difference between basalt and diabase is that the crystals in the former are microscopic in size while in the latter they may be seen with the naked eye. The grain of the rock therefore varies from very fine to coarse. When it assumes the latter condition it often passes under the name of gabbro. In occurrence diabase is very similar to basalt in that it is found both as dikes and in sheets. Sometimes it forms coarser or central portions of large masses of basalt, where the slower cooling has led to a coarser crystallization.

As a road material diabase is usually inferior to basalt because of its coarser crystallization, causing it to break up more rapidly under the influences of the weather. As a rule it is considerably weathered at the surface and stripping must be resorted to in order to secure fresh rock. Diabase has a hardness and a toughness above the average, and almost always it possesses strong cementing value. As a general thing it yields road material of good quality.

Tests were made upon diabase from six different localities in the state, five of these from western and one from eastern Washington. It is likely that at all these places the diabase represents the interior portions of large basalt dikes. It has been used in road building from one of the six localities only, viz., the one at Charleston, Kitsap county.

DIORITE.

In diorite all portions of the rock are entirely crystallized, so that there is no groundmass. As a rule the crystals are intermediate or smaller in size and the grain of the rock is fine rather than coarse. The prevailing minerals are plagioclase feldspar and hornblende, with varying amounts of biotite and augite. Quartz is generally absent, and when present the rock is usually known as a quartz-diorite. Diorite is commonly grayish in color, but becomes darker as the ferro-magnesian minerals increase in quantity. This rock is typical of large masses of molten matter that have cooled far below the surface. This has insured a slow rate of cooling and hence a complete crystallization. Diorite rarely occurs as dikes but as great masses of rock covering considerable areas.

Diorite is not of the highest value as a source of road material. It is of average hardness but is usually low in toughness. On the other hand the cementing properties are likely to be fairly high. The rock decomposes under the weather because of the breaking down of the feldspar. It could be used very satisfactorily in macadam construction if combined with basalt. It would be entirely safe to use it alone if the roads were subjected to moderate traffic only.

Samples were collected at three places, two of them being near Granite Falls, in Snohomish county, and the other near Curlew, in Ferry county. Diorite is a rather common rock in the state, but it is found mostly in the high mountains. Samples were secured from those places only where transportation was convenient.

GABBRO.

Gabbro has essentially the same minerals as basalt and diabase, viz., plagioclase feldspars and pyroxenes. It differs from these in that the crystallization or grain of the rock is much coarser. When the feldspars are in excess the rock is light in color; but the prevailing color is black due to the excess of the ferro-magnesian minerals. Usually the crystals are large and the mineral constituents may be determined with the unaided eye. Gabbro sometimes makes up the central parts of very large dikes, and occasionally it forms the innermost portions of thick sheets of lava. When it appears as a surface rock it is because erosion has stripped off all the mantle above which retarded the cooling of the gabbro.

Specimens of gabbro were collected at Gate, Thurston county, and at Blue Creek, Stevens county. At both places it is closely associated with basalt, indicating that it represents the coarsely crystalline portions of the latter rock. As far as known it is not in use anywhere in the state as a road material. When fresh it has a hardness and a toughness above the average, but with rather low cementing value. It decomposes somewhat readily and is easily influenced by the weather. It is compact and possesses a high specific gravity. It is clearly inferior to basalt for macadam purposes and should not be used if that rock can be had.

GRANITE.

The prevailing minerals in granite are orthoclase feldspar, quartz, and muscovite. Other minerals of frequent occurrence are plagioclase feldspars and biotite, with very small quantities of magnetite, apatite, and zircon. The lighter colored minerals are in excess and hence the resultant rock is usually gray or a related color. The chief factor in determining the color is often the orthoclase feldspar. In granite the crystallization of the minerals has been complete. While some granites are fine grained, more often the crystals are coarse, so the texture is in striking contrast with that of basalt and similar rocks. This rock rarely occurs in dikes but usually in great irregular masses which have solidified from a molten condition at some distance beneath the surface.

Granite is not commonly used for road building purposes. When fresh and unweathered it is very hard but at the same time is quite brittle. Not only does it lack in toughness but its cementing value is low. It has so little of the necessary binding quality which crushed rock should possess that it would often fail in road use. Sometimes it may be recommended for a roadway where the traffic will be moderate or light. At other times it might be satisfactorily used as the basal course in road construction provided that the surface of the highway were made out of basalt or some other good rock. It might be advantageous at times to mix crushed granite with basalt or limestone and roll these into the roadway together.

Granite is a very common rock in the counties of northern Washington. It also occurs along the Snake and Columbia rivers, and at several places in western Washington. It varies in composition from place to place, but shades into other varieties of rocks as its minerals change from one species to another. When the quartz gradually disappears from the rock it merges into a syenite; as the orthoclase feldspar yields in preponderance to plagioclase feldspar, the resultant rock becomes a quartz diorite; while varying percentages of quartz, orthoclase and plagioclase feldspars, give rise to granodiorites and diorites.

GRANODIORITE.

This rock is an intermediate one between granite on the one hand and quartz-diorite and diorite on the other. Both orthoclase and plagioclase feldspars occur in about equal proportions, along with quartz, hornblende, and the micas. The rock more clearly resembles granite than any other, and almost always it is included with the latter except where a technical distinction is made. The general description of granite as to physical properties, mode of occurrence, and value as a road material will apply to granodiorite equally as well.

Granodiorites were collected at eight localities as follows: Leavenworth, Chelan county; near Alkire, Ferry county; Halford, Index, and Scenic, King county; Ruby, Okanogan county; and Camden and Loon Lake, Stevens county. At several of these places quarries are in operation where the rock is sold under the name of granite. Granodiorite is evidently of common occurrence in the state, chiefly in the northern or northeastern counties.

RHYOLITE.

This rock has essentially the same chemical composition as granite, but it differs from the latter in the degree of crystallization. Rhyolite has a groundmass which may be finely crystalline or glassy, with well defined crystals of orthoclase feldspar, quartz, and sometimes biotite and hornblende. In texture, therefore, the rock varies from compact or fine grained to a coarseness where the crystals may be easily seen with the naked eye. The light colored minerals so preponderate in the rock that dark colored rhyolites are uncommon. Rhyolite occurs both as dikes and surface flows. It is a rock in which the rate of cooling has been rapid. When the rate of cooling has been retarded, as at the center of a great lava flow, the crystallization will be complete and granite will be the result.

For use as road material rhyolite does not have many strong points. It is high in silica and hence is not only very hard but is not readily weathered or decomposed. It is very brittle and has a low degree of toughness. It has very poor cementing qualities and does not bind well in macadam work. It might be used to advantage with other rock that possesses desirable binding properties.

Rhyolite is comparatively rare in Washington. Samples were collected and tested from Wenatchee in Chelan county, and from Wolfred in Stevens county.

SYENITE.

Typical varieties of this rock are made up essentially of orthoclase feldspar and hornblende. Besides these minerals, plagioclase feldspar and biotite are very generally present. Syenite is allied to granite, the principal difference being in an almost entire absence of quartz. The color of syenite is light rather than dark, the determining factor being the color of the orthoclase feldspar. The rock is composed entirely of crystals, usually small but sometimes large in size. Syenites belong to a class of rocks that have cooled far enough below the surface to have insured a slow rate of cooling. They usually occur in large masses rather than in small dikes.

For use in road building syenites are open to some of the objections urged against granites. They are very hard but they lack in toughness. Not only are they brittle but their cementing power is not high. However, as a rule, the cementing quality is better developed in syenite than in granite.

Syenite is not a common rock. Samples were collected at only two places in the state, viz., near Wenatchee, in Chelan county, and at Kapowsin, in Pierce county.

VOLCANIC ASH.

A sample of volcanic ash was secured at Meyers Falls, Stevens county. It is a fine grained, greenish gray, highly indurated ash composed essentially of angular fragments of chloritized plagioclase and rock glass cemented together by calcite, quartz and chlorite. It has average hardness but a high degree of toughness. It offers high resistance to wear and possesses fair cementing value.

SEDIMENTARY ROCKS.

LIMESTONE.

Limestone is a sedimentary rock which is almost always of marine origin. It is usually made of the broken fragments of shells which accumulate on the sea-floor, near the continents, but beyond the range of the sediments brought from the land. When the sediments are made exclusively of shells the resultant limstone is pure. With the shells a varying amount of silt or sand may be deposited, giving rise to impure limestone which may grade into calcareous clays or calcareous sandstones. Sometimes the shells may be so thoroughly ground up by wave action that the individual shells can not be recognized in the limestone. Quite often after the limestone is made the shells are dissolved by heated waters that percolate through them and the whole mass then assumes a crystalline condition. This has been so universally true in Washington that shells in the limestone are very uncommon. All of the rock is in a more or less crystalline condition, and the major part of it has been transposed into marble.

Limestone is very much used as a road material in some localities, especially where it is the prevailing country rock. It varies very much in hardness and toughness, and one objection to it has been the ease with which it is usually ground up under heavy traffic. On the other hand it has excellent binding qualities and is noted for its high cementation. It is easily crushed and prepared for the highway and this fact has been favorable to its use. It is not likely that limestone will ever be used in road building in Washington because of its scarcity and the demands upon it for other very necessary uses.

Two samples of limestone were collected for testing. One of these was from Curlew Lake, and the other near Republic, both in Ferry county. They are highly crystalline in character, and mark intermediate conditions between limestone and marble. Similar limestones or marbles are found rather abundantly in Stevens and Ferry counties. They occur in less quantity in Okanogan, Whatcom, San Juan, and Skagit counties. Except for deposits at rare intervals they are unknown in other parts of the state.

SANDSTONE.

This rock is of sedimentary origin and may be made in lakes or in the sea. It is composed essentially of sand, derived mainly from rocks with a high percentage of silica. The hardness of sandstone depends in part upon the kind of cement which binds the sand grains together. When silica is deposited as a cement among the grains a very hard and durable rock results, known as quartzite. Sandstones and quartzites grade very naturally from one into the other. Sometimes during the deposition of the sand upon the sea or lake floor other sediments may be included, due to a failure in the sorting action of the water. When coarser sediments are included, such as gravel, the resultant rock may represent intermediate stages between sandstone and conglomerate. When silt is deposited with the sand the rock may represent gradations from sandstone into shale.

Sandstone is not often used in macadam work because of its low binding power. It usually does not run high in the cementation test. When fresh and unweathered it is a hard rock, especially when silica has been used to any extent as a natural cement to bind the grains of sand together. In the Washington sandstones the ingredients have been generally derived from granitic rocks. In the processes of weathering, erosion, and deposition of the granitic materials the sorting action has been incomplete, so that along with the silica grains there is much feldspar and other minerals. The presence of feldspar adds to the binding qualities of the crushed rock. The sandstones of the state sometimes give high results in the cementation test because of the unusual amount of feldspar present.

This rock occurs very commonly within the Cascades, and between those mountains and the sea. In some places, such as about Bellingham, Wenatchee, Roslyn and elsewhere great lakes were once in existence wherein thick beds of sandstone were laid down. Similar rocks occur in the northeastern counties where smaller lakes were once common. The sandstones of the western margin of the state are of marine origin, having been deposited along the margin of the continent. Samples of sandstone were collected for testing from Cashmere, Chelan county; Raymond, Pacific county; Fidalgo Island, Skagit county; Waldron Island, San Juan county; Colville and Newport, Stevens county; and Wickersham, Deming and Chuckanut, Whatcom county.

METAMORPHIC ROCKS.

GNEISS.

Gneiss is a rock which very commonly has the same mineralogical composition as granite. It differs from granite chiefly in the fact that it is a laminated or banded rock, and possesses this characteristic of a stratified rock. It represents a rock of the granite type that has been so metamorphosed by heat and pressure that it is much altered from its original condition. It is sufficiently like granite in its composition and physical properties that it may be regarded as having the same properties when looked upon as a road material. It ordinarily passes for granite when used commercially and in hand specimens it is sometimes difficult to detect it from granite. Gneiss is not an uncommon rock in the northern counties of the state where metamorphic rocks are the rule. It makes up the canyon walls along Columbia river at many places north of Wenatchee. From Wenatchee down the river for many miles both banks of the stream are strewn with angular blocks of gneiss of great size, which were brought to their present positions by a great glacier which once descended the Columbia. In Wenatchee some of the masses of gneiss have been crushed and used in macadamizing the streets. This rock is well-nigh valueless because it is so deeply weathered that its durability is gone.

MARBLE.

This rock represents a limestone that has been so metamorphosed that it is now in a crystalline condition. The chief agent of metamorphism is water at a high temperature. Marbles are usually made by the folding and deformation of limestones, and hence they are generally produced in mountain building. As far as their road building qualities are concerned they are very similar to limestones. In Washington there are very few places where the limestone has not been wholly changed to marble. When the original limestone was made up of shells only the resultant marble is white in color. Usually there were enough foreign substances in the limestone to cause the marble to vary in color from dark gray to almost black.

The chief localities in Washington where marble occurs are in the northern counties. It outcrops at very many places in Stevens county, but at fewer places in Ferry and Okanogan counties. In these counties the marble is not a pure calcium carbonate as a rule but usually contains a considerable percentage of magnesium carbonate as well. In northwestern Washington marble is found at many places on the San Juan islands, and much more sparingly in Whatcom and Skagit counties. At all these places the rock is an almost pure calcium carbonate, especially free from magnesia. Samples were collected at eight places, and tested for their value as road materials. These localities were as follows: Zindel, Asotin county; Barstow, Ferry county; Oroville and Molson, Okanogan county; Chewelah, Evans, and Northport, Stevens county; and Kendall, Whatcom county.

QUARTZITE.

This is a rock which has been made very compact and hard by the cementation of a sandstone by silica. When heated waters percolate through a sandstone they frequently carry silica in solution which may be precipitated among the sand grains to such a degree that the pore space is all eliminated and the rock becomes essentially one mass of silica or quartz. The degree of metamorphism determines how far the original sandstone is changed over into quartzite. A quartzite is a very hard but brittle rock, and usually the crushed particles do not cement together well in a roadway.

Quartzites are more or less common in the state where the sandstones have been metamorphosed. Like marbles these rocks are more likely to be found where folded strata are the rule. They are generally formed far below the surface and are only exposed after long continued erosion. They were collected at two localities in the state, viz., at Friday Harbor, in San Juan county, and at Steptoe Butte, Whitman county.

SLATE.

Slate is a metamorphic rock which has been formed by the compacting and hardening of shale. Originally it has come from clay and under the weathering influences it will return to that condition again. After the clay or silt is first deposited on the sea-floor or on a lake bottom it is compacted into shale. When the beds of shale are folded or squeezed, as in the process of mountain building, the rock is made so much more compact that slate is the result. The natural associates of slate are marble and quartzite. One of the striking physical properties of slate is its cleavage whereby it will break into thin slabs of large size and remarkable smoothness.

Slate is not commonly used in road building. At times it is very hard but in general it is disposed to be soft, especially where it has weathered to any extent. Its tendency to easy splitting or cleavage causes it to break up readily under traffic. It should not be used when better rocks are available.

This rock occurs at many places in Washington, chiefly in the northern Cascades where metamorphic rocks are the rule. It was collected for testing at only one place, viz., Burlington, in Skagit county.

SERPENTINE.

Serpentine is usually formed by the alteration of a basic igneous rock. Whenever such a rock, composed chiefly of the ferro-magnesian minerals, is acted upon by the agents of metamorphism a hydrous magnesian silicate, known as serpentine, is the result. Serpentine is usually green in color and has a greasy feel. It is a very soft rock, with low toughness and low resistance to wear. It has a high cementing value and this is the only property to recommend it as a road material.

A sample of serpentine was secured at only one place, and that was Granite Falls, Snohomish county. The rock at this place is composed essentially of the minerals serpentine, talc, and magnetite, with minor quantities of bronzite, enstatite, and limonite.

SCHIST.

This is a metamorphic rock with laminations of such a nature that it breaks readily along parallel planes. In this respect it resembles slate, except that the cleavage is not so pronounced. In composition schist often resembles gneiss. As a rule the former is finer grained than the latter. Schist is commonly classified according to the mineral in it which appears to be the most conspicuous. Mica schist is a very common type, where the white mica, muscovite, appears as the ruling mineral.

Schist is of little value as a road material. It is soft, lacking in toughness and resistance to wear, and has only moderate cementing value. One sample only was collected, that being at Wickersham, Whatcom county.

CHAPTER II.

METHODS OF TESTING ROAD MATERIALS, WITH THE RESULTS OF THE TESTS MADE UPON WASHINGTON ROCKS.

In the construction of the best highways a large number of factors are necessarily involved. Among these may be noted the choice of a proper gradient for the roadway, good drainage of the roadbed, the selection of first-class materials for road use, and the application of such materials in the best way known to engineering science. Since this report has to do only with road materials this factor alone will be considered in connection with highway construction.

In the selection of rock for macadam purposes, it is necessary or desirable that competent methods be employed to determine the value of the material. There are in general three methods available for use in the examination of rocks for road building purposes. These are (1) an examination of the rock in the ledge, such as in a quarry or at the natural outcrop, (2) a practical use of the rock in a highway, and (3) laboratory tests upon selected samples.

EXAMINATION OF ROCK IN THE LEDGE.

An examination of the bed-rock at its natural outcrop or in a quarry is usually of value in estimating its desirability for macadam purposes. The resistance which the rock offers to the agents of weathering may be determined usually by the topography of the outcrop. If it projects boldly above the surrounding country the rock has strong powers of resistance and will withstand in a marked degree the ordinary weather attacks. If the bed-rock is deeply buried under an overburden of broken rock and soil which has been produced by the weathering of the rock in place, the chances are that the bed-rock will not yield first-class road material. The chief characteristics of the rock which should be noted in a field examination are the mineral ingredients, coherency, porosity, texture, fracture, and the natural cracks or joints.

MINERAL CONSTITUENTS.

Since all rocks are but aggregates of minerals it is evident that the character of any rock is largely determined by its mineral ingredients. The kinds of minerals, with the relative amounts of each, are important factors. The hardness and the solubility of the rock are determined by such characters in the individual minerals. If the minerals are known to be hard the rock is hard; if there are soluble minerals within the rock the whole mass will gradually fall apart. Solubility is at once both an advantage and a disadvantage. A moderate degree of solubility, when precipitation of the soluble portion takes place within the crushed rock, yields marked binding qualities.

COHERENCY.

The coherency of a rock gives rise to the quality known as toughness, which is a necessary attribute of any stone designed for highway purposes. In igneous rocks, such as granite, the coherency depends upon the extent of interlocking of the crystals. In sedimentary rocks, such as sandstone, the coherency depends mainly upon the degree of cementation of the grains. The toughness of a rock may usually be determined in a practical way by breaking off small pieces of rock from the ledge. The degree of toughness varies with the strength of the blow necessary to disrupt the mass.

POROSITY.

The amount of pore space in a rock may be determined usually by an examination with the eye alone or by means of a small magnifier. In general as the degree of porosity in a rock increases its value for road purposes decreases. This is because of a decline in its specific gravity, a lowering of its crushing strength, and a greater liability to the disruption of the road by frost action. In a sedimentary rock the porosity varies with the size of the water-worn fragments out of which the rock is made, and with the amount of cement which was added after the original deposition of the sediment. In igneous rock, such as basalt, the porosity is usually due to steam holes caused by an original overplus of water.

TEXTURE.

By texture is meant the sizes of the grains which compose the rock. This quality is easily detected with the naked eye. In general the finer the grain the more valuable is the rock as a source of road material. Rocks which are very coarse in grain should not be used when fine-grained ones may be had. As the size of grain increases, especially when the rock is made up of minerals widely different in their co-efficients of expansion, the mass is more readily disrupted through expansion and contraction. This would be the case particularly in a region where rapid changes of temperature are common.

FRACTURE.

The fracture is the kind of surface that is produced when the rock is broken. An even surface is not as desirable as a rough one because it decreases the binding quality of the crushed rock. The conchoidal or shell-like fracture of basalt is regarded as a very desirable one because it renders marked assistance in binding together the broken fragments of rock. The fracture of a rock is one very readily determined by breaking off fragments from the ledge, and observing the character of the broken surfaces.

JOINTING.

The joints are natural cracks or planes which may be found in every ledge or quarry. They are generally in excess near the surface, and decrease with depth. When they occur with proper frequency they are helpful in lowering the cost of quarrying the stone for crushing. When they occur too frequently the rock after it is crushed may have too many surfaces that are smooth rather than rough.

PRACTICAL USE OF THE ROCK.

Since the best tests are always made in the laboratory of experience, the long continued successful use of a rock affords the only test which may be regarded as final. When this test is employed it is desirable to know many things besides the quality of the rock, such as the condition of the roadbed, the method of applying the crushed rock, the care and maintenance of the highway, the nature of the traffic, etc. In the older communities where macadam roads have been in use for many years the test of experience is the most valuable one and the one which should be used as far as possible. In the younger communities, such as those in Washington, so very few macadam roads have been constructed that the test of successful use can rarely be applied in the discussion of what material to use in highway work. For the present the other methods of examination must be depended upon, and the experience test left for the future.

LABORATORY TESTS UPON SELECTED SAMPLES.

The tests which may be performed in the laboratory are valuable supplements to the field examination of a ledge of rock, as described above. The difficulties in the way of a laboratory test are those attendant upon such vast differences in the scale of operations, and upon the impossibility of attaining in the laboratory conditions similar to those of a highway. The results of such tests can only be regarded as approximate, and never as wholly conclusive. The Office of Public Roads, U. S. Department of Agriculture, Washington, D. C., has equipped an excellent laboratory where the tests described below were made and where the utility of rocks for road building are determined. The following statements in explanation of hardness, toughness, resistance to wear, cementing value, and weight per cubic foot are taken from a leaflet entitled "Maximum and Minimum Results on Rock Samples, corrected to January 1, 1910," and published by the Office of Public Roads.

HARDNESS.

By hardness is meant the resistance of a rock to the grinding action of an abrasive agent like sand, and it is tested as follows:

A core one inch in diameter, cut from the solid rock, is faced off and subjected to the grinding action of sand fed upon a revolving steel disk against which the test piece is held with a standard pressure. When the disk has made 1,000 revolutions the loss in weight of the sample is determined. In order to report these results on a definite scale which will be convenient the method has been adopted of subtracting one-third of the resulting loss in weight in grams from 20. Thus a rock losing 6 grams has a hardness of 20—6-3 or 18. Experience has shown this to be the most convenient scale for reporting results. The results of this test are interpreted as follows: Below 14, rocks are called soft; from 14 to 17, medium; above 17, hard.

TOUGHNESS.

By toughness is meant the resistance a rock offers to fracture under impact; such, for instance, as the striking blow given by a shod horse. This property is tested in a specially designed machine built on the pile driver principle, by which a standard weight is dropped upon a specially prepared test piece until it breaks. The height in centimeters of the blow which causes the rupture of the test piece is used to represent the toughness of the specimen. Results of this test are interpreted so that those rocks which run below 13 are called low; from 13 to 19, medium; and above 19, high.

RESISTANCE TO WEAR.

Resistance to wear is a special property in a rock, and although it depends to a large extent upon both the hardness and the toughness of the rock it is not an absolute function of these qualities.

The per cent. of wear in the table refers to the dust and detritus below one-sixteenth of an inch in size worn off in the abrasion test. The test is made in the following manner: Eleven pounds (5 kg.) of broken rock between 1¼ and 2½ inches in size, 50 pieces if possible, are placed in a cast-iron cylinder mounted diagonally on a shaft and slowly revolved 10,000 times.

The French coefficient of wear is obtained by dividing 40 by the per cent. of wear. Thus a rock showing 4 per cent. of wear has a French coefficient of wear of 10. The French engineers, who were the first to undertake road-material tests, adopted this method of recording results. They found that their best wearing rocks gave a coefficient equal to about 20. The number 20 was therefore adopted as a standard of excellence. In interpreting the results of this test a coefficient of wear below 8 is called low; from 8 to 13, medium; from 14 to

20, high; and above 20, very high. Rocks of very high resistance to wear are only suited for heavy traffic.

CEMENTING VALUE.

By cementing value is meant the binding power of the road material. Some rock dusts possess the quality of packing to a smooth, impervious mass of considerable tenacity, while others entirely lack this quality. Cementing value should not be confused with the property possessed by Portland cement, which causes it to set into a hard, stone-like mass when mixed with water. The cementation test is made as follows:

The rock sample is ground in an iron ball mill with sufficient water to form a stiff, fine-grained paste. From this paste small briquettes 1 inch (25 mm.) in diameter and 1 inch high are molded under pressure. After thorough drying the briquettes are tested under the impact of a small hammer which strikes a series of standard blows. The number of blows required to destroy the briquette is taken as a measure of the cementing value of the dust. Some rock dusts, when thoroughly dried into compact masses, immediately slake or disintegrate when immersed in water. It is considered that the tendency to act in this way is not a desirable characteristic of a road material, as it would lead to muddy conditions on the road surface after rains. The test is interpreted so that cementing values below 10 are called low; from 10 to 25, fair; from 26 to 75, good; from 76 to 100, very good; and above 100, excellent.

WEIGHT PER CUBIC FOOT.

The weight per cubic foot refers to the weight of the material in the form of a solid and not as broken stone.

On the following pages Tables A and B represent the results of tests made in the laboratory of the Office of Public Roads. Table A gives the results of tests on rocks which were collected in all parts of the United States, corrected to January 1, 1910. Table B gives the results of tests made upon rocks selected from Washington alone. In order to determine the relative value of any rock mentioned in Table B the results of the test upon it should be compared with those upon the same kind of rock mentioned in Table A.

TABLE A. MAXIMUM AND MINIMUM RESULTS ON ROCK SAMPLES, CORRECTED TO JANUARY 1, 1910.*

No. of Samples.	NAME.	Specific Gravity.			Weight—Pounds per Cubic Foot.			Water Absorbed—Pounds per Cubic Foot.		Per Cent. of Wear.		French Coefficient of Wear.		Hardness.		Toughness.		Cementing Value.	
		Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
40	Andesite	2.95	2.20	2.70	184	137	168	6.59	0.05	8.1	1.5	26.0	4.9	19.4	7.9	44	6	500+	11
83	Basalt	3.00	2.40	2.85	187	150	178	6.32	0.04	14.7	1.3	30.4	2.7	19.2	5.9	39	6	500+	4
183	Diabase	3.20	2.60	2.90	200	162	181	2.73	0.03	6.3	1.1	36.4	6.4	19.4	12.3	54	4	500+	2
57	Diorite	3.35	2.70	2.85	209	168	178	1.08	0.05	7.3	1.6	25.0	5.5	19.4	16.6	38	5	148	5
36	Gabbro	3.65	2.75	2.95	228	172	184	0.97	0.04	5.9	1.3	30.8	6.8	18.8	16.2	23	9	115	6
115	Gneiss	3.20	2.60	2.75	200	162	172	1.24	0.02	16.4	1.7	23.0	2.4	19.3	9.0	25	2	110	1
168	Granite	3.00	2.00	2.65	187	125	165	2.77	0.04	24.6	1.1	37.0	1.6	19.6	13.6	33	2	255	2
573	Limestone	2.90	2.00	2.70	196	125	168	13.22	0.02	34.2	1.8	21.7	1.2	19.1	0.0	25	2	500+	10
20	Marble	2.85	2.65	2.75	178	165	172	1.04	0.10	14.0	2.5	16.0	2.8	17.3	7.1	23	3	85	15
78	Quartzite	3.15	2.50	2.70	196	156	168	1.89	0.05	7.6	1.6	24.5	5.3	19.7	16.5	30	5	45	0
35	Rhyolite	2.90	2.05	2.55	181	128	159	7.15	0.03	9.7	1.7	23.0	4.1	19.7	15.3	42	6	500+	10
244	Sandstone	3.25	2.00	2.65	208	125	165	11.60	0.02	41.7	1.0	40,8	1.0	19.5	0.0	60	2	500+	1
114	Schist	3.20	2.65	2.90	200	165	181	1.35	0.06	18.2	1.3	31.7	2.2	19.0	0.9	85	3	232	5
45	Slate	3.35	2.60	2.75	200	162	172	2.10	0.05	12.4	1.6	24.4	3.2	19.7	1.1	56	1	500+	1
26	Syenite	3.05	2.15	2.70	190	134	168	4.21	0.06	14.4	1.7	23.5	2.8	19.2	17.3	34	8	375	16

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* Tested in the Laboratory of the Office of Public Roads, United States Department of Agriculture. Samples taken from all parts of the United States.

TABLE B. RESULTS OF TESTS MADE UPON CERTAIN ROAD MATERIALS OF WASHINGTON.

[Tested in the Laboratory of the Office of Public Roads, United States Department of Agriculture.]

Serial No.	LOCALITY.	Kind of Rock.	Specific gravity	Weight per cubic foot in pounds	Water absorbed per cubic foot in pounds	Per cent. of wear	French coefficient of wear	Hardness	Toughness	Cementing value	General value
	Adams County—										
1	Lind	Basalt	2.95	184	0.24	2.2	18.4	18.3	14	Fair	Satisfactory
	Asotin County—										
2	Asotin (Sittkes quarry)	Basalt	2.95	184	0.12	2.3	17.2	18.0	20	Good	Very good
3	Zindel (Rogers mountain)	Marble	2.70	168	0.14	7.5	5.3	*	*	Fair	Fair
	Benton County—										
4	Prosser (county pit)	Basalt b'lders	2.85	178	0.17	2.2	18.2	18.4	11	Good	Very good
5	Kiona (3½ miles west)	Basalt	2.90	181	0.30	2.1	19.0	18.8	20	Good	Very good
	Chehalis County—										
6	Hoquiam	Basalt	2.85	178	0.37	2.2	18.5	18.2	27	Good	Very good
7	Oakville (1 mile west)	Basalt	2.90	181	0.26	3.6	11.1	16.8	14	Excellent	Excellent
	Chelan County—										
8	Wenatchee (boulders)	Gneiss	2.70	168	0.21	5.2	7.8	*	*	Good	Not recommended
9	Wenatchee (2 miles southwest)	Rhyolite	2.30	143	2.16	*	*	*	*	Good	Not recommended
10	Cashmere (1⅝ miles northwest)	Sandstone	2.60	162	0.79	6.4	6.3	*	*	Good	Not recommended
11	Leavenworth	Granodiorite	2.75	172	0.40	7.0	5.7	17.0	4	Fair	Fair
	Clarke County—										
12	Fisher	Basalt	2.85	178	0.30	2.9	13.8	18.0	25	Fair	Satisfactory
13	Yacolt (3 miles south)	Basalt	2.80	175	0.27	2.5	15.8	16.8	15	Excellent	Excellent
	Columbia County—										
14	Dayton	Basalt	2.85	178	0.56	2.3	17.4	17.7	21	Low	Good

	Cowlitz County—										
15	Kalama (¾ mile south)	Basalt	2.80	175	0.14	8.8	12.0	15.4	10	Good	Satisfactory
16	Kalama (½ mile south)	Basalt	2.80	175	0.20	8.3	12.2	16.7	10	Good	Satisfactory
17	Kalama (2 miles north)	Basalt	2.80	175	0.27	8.2	12.5	16.8	15	Excellent	Excellent
18	Carrollton (1½ miles northeast)	Basalt	2.85	178	0.10	8.8	12.1	17.3	6	Good	Satisfactory
19	Kelso (1½ miles southeast)	Basalt	2.80	175	0.83	3.9	10.1	14.3	7	Excellent	Fair
20	Kelso (2 miles north)	Basalt	2.90	181	0.12	3.8	10.4	18.0	10	Excellent	Excellent
21	Castle Rock	Basalt	2.85	178	0.42	5.2	7.7	17.4	11	Excellent	Satisfactory
22	Ladu (Star Sand Company)	Basalt	2.95	184	0.11	1.9	20.6	18.0	22	Good	Excellent
23	Ladu (2 miles north)	Basalt	3.00	187	0.29	2.4	16.5	18.8	13	Fair	Satisfactory
24	Stella (1 mile west)	Basalt	2.70	168	1.77	2.5	16.1	18.5	14	Low	Satisfactory
25	Stella	Basalt	2.90	181	0.23	2.8	14.1	17.2	16	Fair	Satisfactory
26	Stella (1½ miles west)	Basalt	2.90	181	0.27	*	*	18.3	22	Low	Satisfactory
	Douglas County—										
27	Columbia river (1½ miles north)	Basalt	2.85	178	0.18	*	*	19.0	20	Fair	Satisfactory
28	Vulcan (1 mile northeast)	Basalt	2.85	178	0.15	2.0	20.0	18.0	17	Fair	Satisfactory
	Ferry County—										
29	Republic (1½ miles north)	Basalt	2.55	159	0.13	5.1	7.8	*	*	Low	Fair
30	Republic (5 miles west)	Limestone	2.70	168	0.14	8.9	4.5	14.8	4	Fair	Not recommended
31	Curlew Lake (east side)	Limestone	2.75	172	0.30	6.6	6.1	17.0	5	Good	Fair
32	Curlew	Andesite	2.65	165	0.64	3.1	12.9	17.9	18	Excellent	Excellent
33	Curlew (4 miles west)	Diorite	2.80	175	0.25	3.6	11.1	17.5	10	Good	Satisfactory
34	Curlew (7 miles west)	Granite	2.70	168	0.23	4.4	9.0	18.1	8	Fair	Not recommended
35	Danville (1 mile south)	Andesite	2.65	165	1.66	2.9	13.8	18.5	17	Good	Satisfactory
36	Laurier (¾ mile south)	Granite	2.60	162	0.29	5.3	7.5	18.5	4	Low	Not recommended
37	Barstow	Marble	2.80	175	0.68	5.6	7.2	17.1	7	Fair	Fair
38	Alkire (3 miles north)	Andesite	2.65	165	0.27	6.5	6.2	*	*	Good	Fair
39	Alkire (14 miles south)	Granodiorite	2.70	168	0.35	3.9	10.2	17.9	12	Fair	Fair
40	Keller (8½ miles north)	Andesite	2.70	168	0.14	3.0	18.3	18.3	13	Excellent	Good
	Franklin County—										
41	Kahlotus (¾ miles east)	Basalt	2.85	178	0.16	2.9	14.0	17.6	16	Low	Satisfactory
	Grant County—										
42	Coulee City (1¼ miles northwest)	Basalt	2.95	184	0.30	2.1	18.7	18.3	21	Low	Satisfactory
43	Coulee City (1 mile south)	Basalt	2.85	178	0.20	2.1	19.4	18.5	22	Good	Excellent
44	Bacon	Basalt	2.80	175	0.52	2.7	14.8	18.1	17	Excellent	Excellent
45	Adrian (1 mile east)	Basalt	2.90	181	0.31	2.7	14.8	18.0	13	Fair	Satisfactory
46	Ephrata (3½ miles southwest)	Basalt	2.95	184	0.14	2.5	16.3	*	*	Good	Very good
47	Crater (1 mile northwest)	Basalt	2.85	178	0.27	2.2	17.9	*	*	Fair	Satisfactory
	Jefferson County—										
48	Port Ludlow (Basalt point)	Basalt	2.85	178	0.29	3.8	10.6	*	*	Fair	Satisfactory
49	Quilcene (3 miles south)	Basalt	2.90	181	0.15	3.4	11.9	18.0	21	Excellent	Excellent
50	Brinnon (2½ miles south)	Basalt	2.90	181	0.17	2.9	13.9	*	*	Excellent	Excellent
51	Duckabush (2 miles south)	Basalt	2.90	181	0.34	4.5	8.9	12.0	6	Excellent	Good

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* Not determined.

TABLE B. RESULTS OF TESTS MADE UPON CERTAIN ROAD MATERIALS OF WASHINGTON.—Continued.

Serial No.	LOCALITY.	Kind of Rock.	Specific gravity	Weight per cubic foot in pounds	Water absorbed per cubic foot in pounds	Per cent. of wear	French coefficient of wear	Hardness	Toughness	Cementing value	General value
	King County—										
52	Duwamish	Basalt	2.65	165	0.36	2.8	14.2	16.8	18	Good	Excellent
53	Earlington (1 mile north)	Andesite	2.50	156	3.07	4.5	8.9	13.8	12	Excellent	Fair
54	Snoqualmie (1 mile south)	Andesite	2.75	172	0.22	2.9	13.6	17.5	23	Fair	Satisfactory
55	Halford	Granodiorite	2.70	168	0.17	4.1	9.7	18.1	9	Fair	Fair
56	Scenic	Granodiorite	2.75	172	0.19	*......	*......	18.3	7	Fair	Not recommended
57	Hot Springs (1 mile west)	Basalt	2.80	175	0.07	2.7	14.6	17.7	25	Low	Satisfactory
58	Veazie (1 mile south)	Diabase	2.75	172	0.55	3.2	12.4	17.0	11	Excellent	Excellent
59	Franklin	Basalt	2.70	168	3.04	3.7	10.7	16.6	9	Excellent	Satisfactory
60	Hobart (2 miles east)	Andesite	2.85	178	0.20	3.9	10.3	17.2	21	Low	Satisfactory
	Kitsap County—										
61	Charleston (2½ miles southwest)	Diabase	2.90	181	0.15	3.3	12.2	17.3	16	Very good	Excellent
	Kittitas County—										
62	Roza	Basalt	2.85	178	0.80	1.7	24.1	17.7	32	Low	Satisfactory
63	Umptanum (2 miles north)	Basalt	2.80	175	0.64	2.1	18.9	18.0	23	Low	Satisfactory
64	Thorp (4 miles northwest)	Basalt	2.85	178	0.42	2.3	17.4	18.4	27	Low	Satisfactory
65	Easton (1 mile west)	Syenite	2.55	159	1.28	1.6	25.6	*......	*......	Fair	Satisfactory
	Klickitat County—										
66	Cliffs (1¼ mile west)	Basalt	2.95	184	0.12	2.6	15.6	18.0	18	Fair	Satisfactory
67	Lyle (¾ mile east)	Basalt	2.80	175	0.43	3.4	11.8	17.2	13	Good	Good
68	Lyle (1 mile west)	Basalt	2.95	184	0.12	*......	*......	17.7	19	Good	Satisfactory
69	Bingen	Basalt	2.80	175	0.29	2.6	15.4	18.7	40	Fair	Satisfactory
	Lewis County—										
70	Meskill	Basalt	2.85	178	0.27	2.3	17.5	15.3	17	Fair	Satisfactory
	Lincoln County—										
71	Davenport (2 miles northwest)	Basalt	2.85	178	0.35	3.2	12.7	13.3	8	Fair	Satisfactory
72	Davenport (3½ miles northwest)	Basalt	2.90	181	0.45	3.1	13.1	18.3	20	Good	Very good
74	Wilbur (2 miles northeast)	Basalt	2.90	181	0.79	1.7	23.0	18.3	20	Fair	Satisfactory
75	Wilbur	Basalt	2.80	175	1.09	3.4	11.8	*......	*......	Good	Satisfactory
76	Govan	Basalt	2.90	181	0.73	2.1	19.4	18.9	21	Fair	Good
77	Almira (¾ mile northeast)	Basalt	2.90	181	0.61	1.9	20.8	18.2	20	Fair	Good
78	Almira (1½ mile south)	Basalt	2.90	181	0.48	2.9	14.0	18.2	24	Good	Excellent
73	Sprague (1 mile southwest)	Basalt	2.95	184	0.20	2.2	17.9	17.0	20	Fair	Satisfactory

	Mason County—										
79	Hamahawa (1 mile north).............	Basalt........	2.85	178	0.67	4.2	9.4	13.8	7	Excellent	Satisfactory
80	Hoodsport (2 mile north).............	Andesite......	2.50	156	2.62	4.1	9.8	13.1	9	Excellent	Fair
	Okanogan County—										
81	Oroville (2 mile southwest)............	Marble	2.80	175	0.50	8.3	4.8	*......	*......	Fair	Not recommended
82	Oroville (3 miles northwest)...........	Andesite......	2.65	165	0.88	2.5	16.2	19.1	18	Fair	Satisfactory
83	Molson (½ mile west)..................	Marble	2.85	178	0.25	*......	*......	16.3	5	Fair	Fair
84	Ruby Mine	Granodiorite.	2.80	175	0.09	3.5	11.6	17.8	11	Low	Fair
	Pacific County—										
85	South Bend (1 mile northeast).........	Basalt........	2.85	178	0.85	4.0	9.9	18.7	8	Excellent	Very good
86	South Bend (1 mile south).............	Basalt........	2.80	175	1.68	3.7	10.8	17.5	10	Low	Satisfactory
87	Raymond (1½ mile northwest)..........	Sandstone....	2.55	159	2.40	4.9	8.2	4.4	6	Good	Not recommended
88	Holcomb (1½ miles southeast)..........	Basalt........	2.30	143	4.87	4.1	9.8	5.7	6	Excellent	Not recommended
89	North river (mouth)...................	Basalt........	2.90	181	0.57	2.9	13.6	16.6	6	Excellent	Satisfactory
90	North river (3 miles above mouth)....	Basalt........	2.85	178	0.65	3.9	10.3	13.7	8	Excellent	Good
91	Nasel river (mouth)...................	Diabase	3.00	187	0.22	*......	*......	*......	*......	Low	Fair
92	Ilwaco	Basalt........	2.40	150	0.89	4.8	8.3	12.8	10	Good	Fair
93	Ilwaco (ocean view)..................	Basalt........	2.55	159	2.13	5.1	7.9	11.0	10	Excellent	Good
	Pierce County—										
94	Kapowsin	Syenite	2.70	169	0.21	2.9	14.0	18.6	11	Good	Good
95	Eatonville (2 miles north).............	Andesite......	2.45	153	0.36	3.7	10.8	17.7	18	Good	Excellent
96	La Grande	Andesite......	2.70	168	0.11	2.2	18.2	19.2	35	Fair	Excellent
97	Elbe	Andesite......	2.65	165	0.36	4.1	9.8	18.4	9	Good	Fair
98	Elbe	Andesite......	2.65	165	0.18	6.6	6.0	*......	*......	Good	Not recommended
	San Juan County—										
99	Friday Harbor	Quartzite.....	2.75	172	0.17	2.8	14.3	18.0	19	Excellent	Satisfactory
100	Richardson	Andesite......	2.90	181	0.27	2.5	16.0	18.3	24	Excellent	Excellent
101	Olga	Andesite......	2.95	184	0.07	4.2	9.5	17.8	19	Good	Very good
102	Waldron Island	Sandstone....	2.60	162	0.66	3.1	12.9	13.2	8	Fair	Not recommended
	Skagit County—										
103	Fidalgo	Sandstone....	2.70	168	0.81	2.5	15.9	18.5	13	Good	Satisfactory
104	Burlington (2 miles northeast).........	Basalt........	3.00	187	0.02	2.9	13.9	18.7	30	Fair	Satisfactory
105	Burlington (½ mile north)..............	Slate	2.75	172	0.21	*......	*......	11.3	6	Fair	Not recommended
106	Clear Lake (2½ miles south)...........	Diabase	2.95	184	0.15	2.1	18.9	18.0	20	Good	Satisfactory
107	Concrete (3 miles west)................	Diabase	2.95	184	0.22	3.4	11.9	19.3	20	Good	Very good
108	Rockport	Andesite......	2.95	184	0.11	10.6	3.8	16.5	18	Good	Fair
	Skamania County—										
109	Cape Horn	Basalt........	2.80	175	0.66	3.0	13.2	19.3	19	Fair	Very good
110	Cook (1 mile west)....................	Basalt........	2.80	175	0.98	2.3	17.4	18.2	33	Excellent	Excellent

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* Not determined.

TABLE B. RESULTS OF TESTS MADE UPON CERTAIN ROAD MATERIALS OF WASHINGTON.—Continued.

Serial No.	LOCALITY.	Kind of Rock.	Specific gravity	Weight per cubic foot in pounds	Water absorbed per cubic foot in pounds	Per cent. of wear	French coefficient of wear	Hardness	Toughness	Cementing value	General value
	Snohomish County—										
111	Granite Falls (1¼ miles northeast)	Diorite	2.70	168	0.42	2.7	14.6	18.7	17	Fair	Good
112	Granite Falls (county property)	Serpentine	2.65	165	0.38	8.0	5.0	*	*	Excellent	Not recommended
113	Granite Falls (1 mile east)	Diorite	2.70	168	0.43	3.2	12.7	18.3	17	Fair	Good
114	Monroe (6 miles south)	Andesite	2.65	165	0.74	4.3	9.3	15.0	8	Good	Good
115	Monte Cristo (1½ miles north)	Andesite	2.75	172	0.12	2.3	17.7	18.3	12	Fair	Good
116	Index (½ mile west)	Granodiorite	2.70	168	0.23	3.1	12.9	17.6	8	Fair	Fair
	Spokane County—										
117	Hillyard (1 mile north)	Basalt	2.70	168	1.22	2.5	15.8	18.8	24	Fair	Very good
118	Hillyard (1 mile north)	Granite	2.70	168	0.29	4.0	10.1	18.8	7	Fair	Not recommended
119	Wayside	Basalt	2.80	175	0.23	1.5	26.7	18.2	35	Low	Fair
120	Dart	Basalt	2.80	175	0.65	2.0	20.4	17.7	19	Low	Fair
121	Milan	Granite	2.70	168	0.61	3.2	12.4	*	*	Good	Fair
122	Marshall (1½ miles south)	Basalt	2.85	178	0.62	2.2	17.9	18.5	30	Low	Satisfactory
123	Marshall (west of)	Basalt	2.90	181	0.30	*	*	18.0	12	Fair	Satisfactory
124	Marshall (1½ miles northeast)	Basalt	2.80	175	0.63	*	*	19.0	24	Low	Satisfactory
125	Cheney (1 mile northeast)	Basalt	2.90	181	0.20	*	*	17.7	10	Excellent	Satisfactory
126	Medical Lake (1½ miles east)	Basalt	2.95	184	0.19	3.0	13.3	*	*	Low	Satisfactory
127	Medical Lake (½ mile east)	Granite	2.70	168	0.29	3.0	13.5	18.3	11	Fair	Not recommended
128	Spokane (near south line)	Basalt	2.95	184	0.63	*	*	17.2	13	Low	Satisfactory
129	Highland (2 miles south)	Basalt	2.80	175	0.90	3.0	13.4	17.9	*	Low	Satisfactory
	Stevens County—										
130	Loon Lake (2 miles southeast)	Granodiorite	2.70	168	0.38	3.9	10.2	18.7	8	Fair	Fair
131	Springdale	Basalt	2.80	175	0.77	2.4	17.0	*	*	Low	Satisfactory
132	Valley (4½ miles west)	Basalt	2.80	175	0.58	2.6	15.4	17.3	12	Low	Satisfactory
133	Chewelah (1 mile east)	Marble	2.85	178	0.34	4.2	9.5	14.8	11	Good	Fair
134	Blue Creek	Gabbro	3.05	190	0.12	2.7	14.8	18.3	17	Fair	Satisfactory
135	Addy (2 miles north)	Granite	2.70	168	0.20	3.0	13.5	18.7	18	Good	Fair
136	Orin (1 mile southeast)	Granite	2.70	168	0.38	5.3	7.5	18.1	4	Fair	Not recommended
137	Colville (2½ miles northwest)	Sandstone	2.45	153	0.31	*	*	*	*	Fair	Fair
138	Kettle Falls (1 mile northeast)	Diabase	2.75	172	0.45	2.9	13.6	16.1	12	Good	Good
139	Meyers Falls	Volcanic ash	2.75	172	0.11	2.8	14.3	16.9	23	Fair	Satisfactory

140	Evans	Marble	2.70	168	2.19	5.4	7.4	14.7	8	Fair	Fair
141	Northport (2½ miles southwest)	Marble	2.70	168	0.12	4.9	8.2	12.4	6	Fair	Fair
142	Camden (1 mile northeast)	Granodiorite	2.75	172	0.26	5.0	8.0	18.2	8	Fair	Fair
143	Newport (2 miles northwest)	Sandstone	2.70	168	0.75	3.0	13.3	18.8	*	Low	Not recommended
144	Wolfred (1½ miles south)	Granite	2.65	165	0.83	2.0	20.4	18.7	19	Fair	Fair
145	Wolfred (2 miles west)	Rhyolite	2.70	168	0.51	2.6	15.4	18.7	6	Fair	Fair
146	Ruby (2 miles northwest)	Granite	2.70	168	0.29	3.4	11.9	18.8	6	Fair	Not recommended
	Thurston County—										
147	Tumwater	Basalt	2.95	184	0.20	2.3	17.5	17.7	20	Good	Satisfactory
148	Mud Bay	Basalt	3.05	190	0.10	2.5	15.9	18.7	14	Good	Very good
149	Gate (3 miles northeast)	Gabbro	2.75	172	0.15	5.9	6.8	13.3	8	Good	Fair
150	Gate (2 miles northeast)	Basalt	2.80	175	0.57	4.1	9.7	11.2	7	Excellent	Fair
151	Gate (1½ miles west)	Basalt	2.90	181	0.11	3.6	11.1	11.0	5	Excellent	Fair
	Wahkiakum County—										
152	Cathlamet	Basalt	2.80	175	0.30	3.1	18.0	17.8	11	Fair	Satisfactory
153	Cathlamet (3½ miles northeast)	Basalt	2.70	168	0.47	2.9	13.8	17.4	9	Good	Satisfactory
154	Cathlamet (3 miles northeast)	Basalt	2.90	181	0.22	1.9	21.3	17.7	24	Fair	Satisfactory
155	Skamokawa	Basalt	2.80	175	0.41	2.2	17.9	18.4	23	Fair	Satisfactory
	Walla Walla County—										
156	Dixie	Basalt	2.90	181	0.39	2.7	14.7	17.2	6	Fair	Satisfactory
157	Waitsburg	Basalt	2.75	172	0.35	2.2	18.2	17.7	22	Low	Satisfactory
158	Lamar	Basalt	2.90	181	0.24	2.5	16.0	18.5	25	Fair	Satisfactory
159	Touchet (2 miles west)	Basalt	2.75	172	0.42	3.2	12.5	18.0	6	Excellent	Satisfactory
	Whatcom County—										
160	Wickersham (2 miles northwest)	Schist	2.70	168	0.47	23.3	1.7	*	*	Low	Not recommended
161	Wickersham (5 miles northwest)	Sandstone	2.60	162	0.93	15.9	2.5	9.2	5	Very good	Not recommended
162	Deming	Sandstone	2.45	153	2.81	8.2	4.9	8.3	5	Excellent	Not recommended
163	Kendall (2 miles north)	Marble	2.75	172	0.20	4.9	8.2	12.3	7	Fair	Fair
164	Chuckanut (3 miles south)	Sandstone	2.50	156	2.03	8.3	4.8	*	*	Fair	Not recommended
	Whitman County—										
165	Colfax	Basalt	2.80	175	0.11	2.0	20.2	19.2	38	Fair	Good
166	Pullman (1 mile south)	Basalt	2.90	181	0.15	2.3	17.2	*	*	Fair	Satisfactory
167	Palouse	Basalt	2.95	184	0.11	2.3	17.7	18.2	22	Good	Good
168	Steptoe Butte	Quartzite	2.65	165	0.40	5.2	7.7	18.7	9	Low	Not recommended
169	Rosalia (1 mile southeast)	Basalt	2.80	175	0.29	2.7	14.7	17.6	26	Fair	Satisfactory
170	Winona	Basalt	2.90	181	0.15	2.5	16.2	19.0	25	Good	Excellent
	Yakima County—										
171	North Yakima (2 miles northwest)	Basalt	2.90	181	0.34	2.5	16.3	18.0	19	Fair	Good

* Not determined.

CHAPTER III.

THE DISTRIBUTION OF ROAD MATERIALS WIT THE STATE, BY COUNTIES.

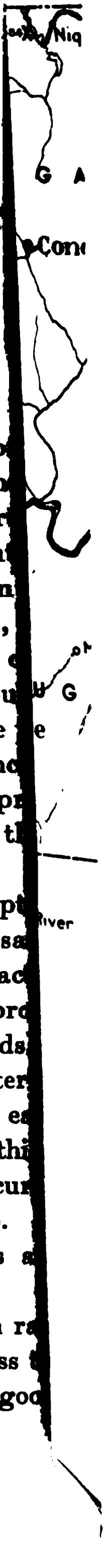
ADAMS COUNTY.

GENERAL STATEMENT.

Adams county is located in the eastern plateau region o state, and varies in elevation from 2,000 feet in the north ern portion to 700 or 800 feet in the southwestern par Columbia river is approached. The surface of the coun made up of shallow valleys with rolling uplands between stream courses. The valleys are locally known as coulees, are usually wide with flat bottoms and bordered with low of rock. There are but few permanent streams in the cou the majority of them being of the intermittent type. The cipitation is largely in the form of snow and the princ run-off of the streams is in the late winter or early sp months. All the streams dry up in the summer except t which head in lakes or permanent springs.

The principal bed-rock of the county is basalt, except the southwest corner where some stratified deposits of sa stones and shales occur. The basalt varies much in charac ranging from a compact, fine-grained black rock to a porc brittle rock having a brownish color, with numerous beds red pumice, yellowish ash and more or less fragmental mater The sedimentary rocks noted above form the low rounded ea ern hills of Saddle mountain where sections 100 feet in thi ness are exposed. Outcrops of the same kinds of rock occur railway cuts for several miles north and east of Othello. general this formation consists of soft gray sandstones a yellow or buff shales, usually in thin layers.

All parts of the county are now very well supplied with ra ways. Three lines of railway, with some branch lines, cross county in different directions. The public roads are not goo



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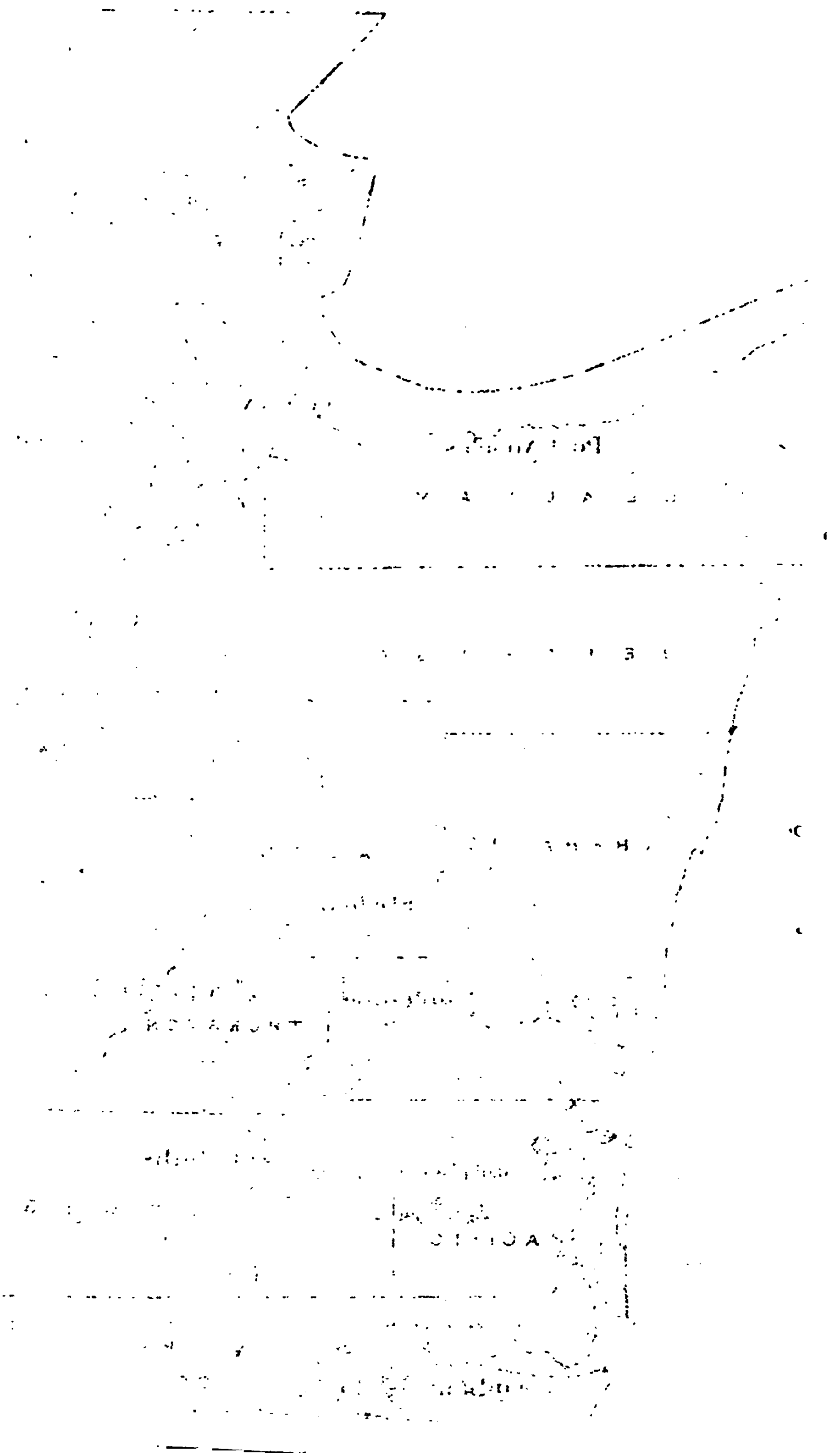


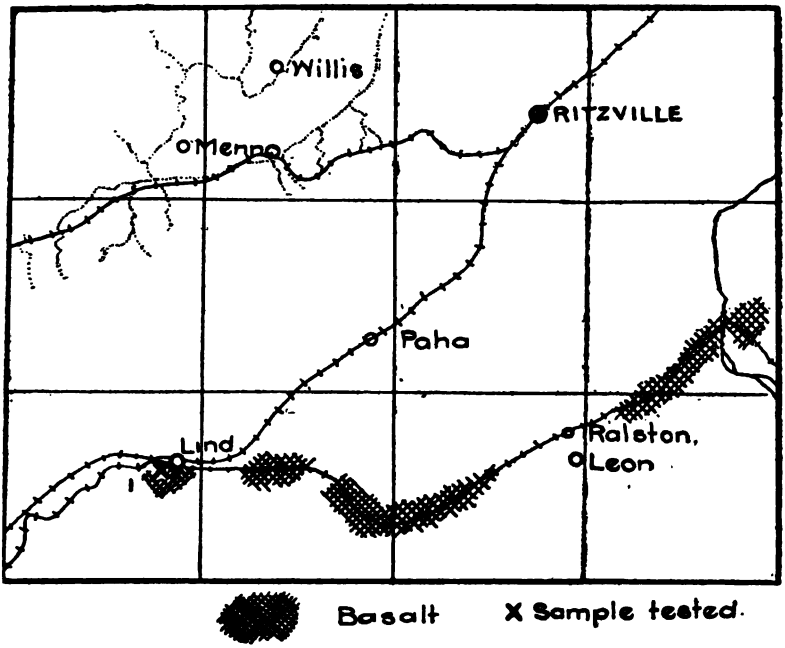


FIG. 1. Central part of Adams county.
Scale, 1 inch equals 6 miles.

being poorly laid out, very dusty in summer, and muddy in winter and spring. The larger towns are without connection by even fairly good roads and neighboring towns on different railway lines are without proper means of communication. A system of main thoroughfares, properly graded and drained, is urgently needed. Such roads should be covered with crushed rock, beginning at the larger towns, and carrying the work into the country as rapidly as possible.

ROAD MATERIALS TESTED.

Serial Number 1.

This sample was taken from the south side of the coulee one-half mile west of the Chicago, Milwaukee & Puget Sound Railway station at Lind. The material is a dense, fine-grained, gray black basalt. It is a hard rock with average toughness, high resistance to wear and fair cementing value. It is a satisfactory rock to use on macadamized streets or roads. At the point where the sample was taken considerable rock has already been removed and the face of the cliff exposed for a hight of 20 feet. A face much higher than this can not readily be secured owing to the gentle slope of the coulee wall at this point. The best rock occurs in vertical columns varying from 18 to 30 inches in diameter, and broken or jointed quite regularly about every two feet. The rock splits in blocks quite readily, and when finally broken has a decided conchoidal fracture with sharp edges. The slight overburden of soil is readily removable, and access to the quarry is easy by wagon road. This rock has been used to some extent for foundation blocks, retaining walls, etc., for which it is well adapted on account of its being easily worked. It would be useful for paving blocks, and as a road material it is probably the best in the county. Thus far no road surfacing has been done in this part of the county.

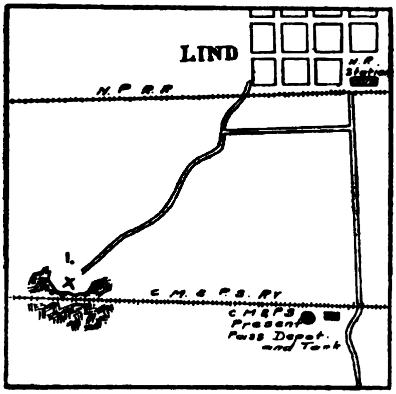


FIG. 2. Position of basalt quarry, near Lind.

There is but little road material that is good in the remaining parts of the county. Along the Chicago, Milwaukee and Puget Sound railway east of Lind rock cuts are very common. The rock is usually quite porous and not very desirable for road purposes. Near Vassar there is some good black basalt which is deeply covered with soil. There is a small bed of gravel two miles east of Lind and other similar deposits between Marengo and Paxton.

Basalt is very abundant from Washtucna to Benge, along the valley of Cow creek. The quality is usually good, and the rock is in columns which in some places might be conveniently quarried. The cliffs are generally quite low and somewhat difficult of access. Much overburden is rare as there is only occasionally a deep soil covering. Basalt in low cliffs is often exposed as a rim-rock along the Lind and Providence coulees. At almost all these places it is so porous and mixed with pumice that it is unwise to use it for macadam purposes. Good quarry sites, convenient to Adams county, where satisfactory road materials may be economically secured are at Kahlotus, Lamont and Sprague.

ASOTIN COUNTY.

GENERAL STATEMENT.

Asotin is the extreme southeastern county of the state and extends from the broad and deep valley of the Snake river on one side to the summit line of the Blue mountains on the other. Apart from the valleys of Snake and Grand Ronde rivers the county is in the main a plateau region, deeply dissected by canyons. The great variation in topography leads to considerable differences in the amount of yearly rainfall. The precipitation along the deeper valleys is so low that irrigation is necessary for agriculture; upon the plateaus and foothills of the mountains the rainfall is ample for the growth of wheat and other cereals; upon the higher mountains there is a good forest growth of pines, firs and other conifers.

All the county at one time was deeply covered by flows of basalt rock. Along Snake and Grand Ronde rivers cliffs of basalt aggregating 2,000 feet in height are common. Lesser cliffs of basalt border the smaller canyons and throughout the whole county there is wide distribution of this rock. Interstratified with the layers of basalt there are occasional beds of rock composed of fragmental materials which were deposited in small lakes. One of these localities is two miles north of Asotin along Snake river. The rock varies in color from light blue-gray to yellowish brown, and is composed of ashes, cinders, and fragments of basalt that have been compacted and cemented into a solid mass. Some of this rock has been used for building

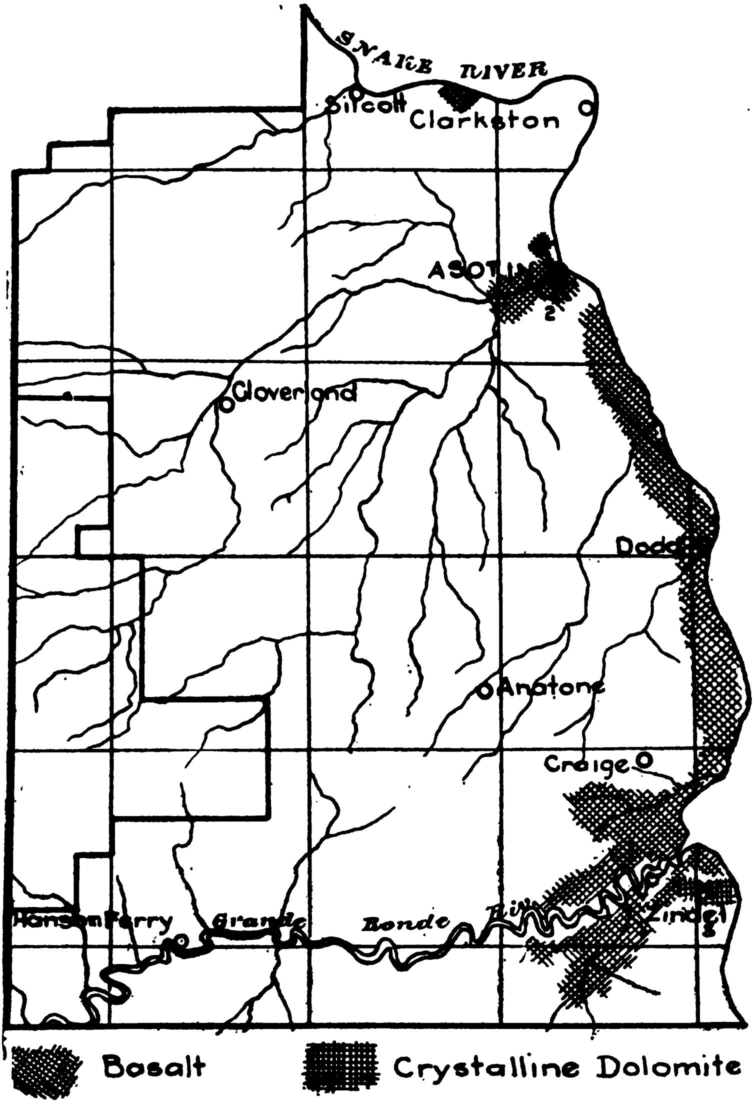


FIG. 3. Eastern part of Asotin county.
Scale, 1 inch equals 6 miles.

purposes, but is not desirable for road making. It is quite soft when quarried and cuts readily, but hardens considerably on exposure. It may prove to be of considerable value for decorative cut stone work.

At the base of the cliffs along Snake river certain rocks appear which are older than the basalt and which have only been brought to view because of the extensive erosion of the basalt. These rocks are mainly granite, limestone, and dolomite and they made up the earlier floor of the county over which the basalt flowed. One of the prominent granite localities is at the mouth of Birch creek, on Snake river, south of the mouth of the Grand Ronde. Immediately south of the mouth of the latter stream, and overlooking Snake river, is a large deposit of dolomite which has been changed into marble. The granite, marble, and all the more compact basalt are useful in road building. Along Snake river the many bars yield gravels which may also be readily obtained for use in surfacing roads.

The great majority of the people in the county live in the valleys of Snake river and its larger tributaries. A system of good roads is needed to connect the larger towns of the valleys. The principal road of the county at present is the Clarkston-Asotin road which leads on southward to Anatone. The latter section of the road, that from Asotin to Anatone, is fairly good in summer when it packs well but is nearly impassible during the rainy season. The Clarkston-Asotin road is a poor one at all times, dusty as well as rocky in summer, and muddy in winter. With a good quality of road building materials well distributed over the county, it should not be long until the main roads are properly graded and surfaced.

ROAD MATERIALS TESTED.

Serial Number 2.

This sample was taken from Sittke's quarry, about one-half mile south of the town of Asotin. The rock is a dense, fine-grained, dark gray basalt. It is hard and tough, has high resistance to wear, and possesses good cementing value. It is very good material for crushed rock for street and road construction. The rock is in the form of columns, with frequent cracks or joints, making it easily workable. Enough stone has been taken out to make a face 35 feet in height, and the extension of the quarry floor into the hill would readily provide a working face from 100 to 150 feet high. The quarry floor is about 250 feet above the flat on which the town is situated and is reached by a wagon road. The soil covering on the rock is thin, and in many places wholly absent. There is an opportunity here for the establishment of an economical crushing plant, with a gravity system, using excellent rock that is inexhaustible in quantity.

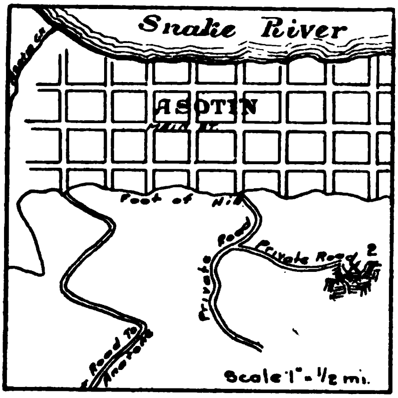


FIG. 4. Basalt quarry near Asotin.

There is a cliff of excellent columnar basalt along the south bank of Snake river four miles west of Clarkston. The columns average about eighteen inches in diameter and have a vertical position. The rock forms a bold cliff 100 feet high and several hundred feet long. The material from this locality could be very readily transported by water.

Serial Number 3.

This sample was taken from the side of Rogers mountain, overlooking Snake river, at a point about one mile south of the mouth of Grand Ronde river. The nearest postoffice is Zindel, on the Grande Ronde, about two miles west. The rock is a dolomite which has been so altered that it is now a marble. It is comparatively soft and when tested showed that it had low resistance to wear. It possesses fair cementing value and could be used in road construction for all highways except those having heavy traffic. In appearance it is a massive gray to black rock, at times considerably jointed. To this time it has not been used for any purpose, chiefly because of a lack of trans-

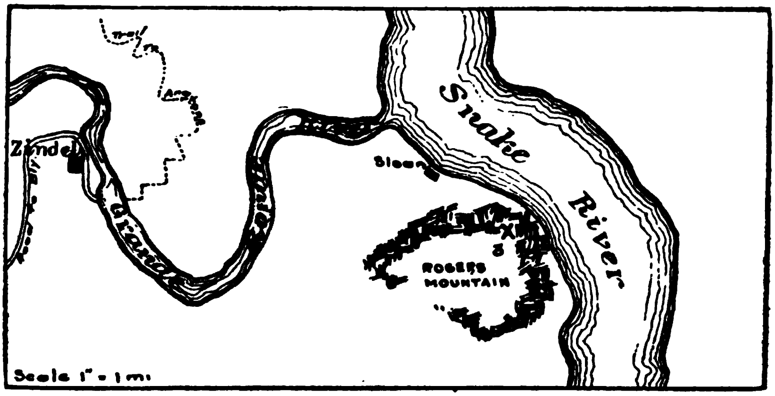


FIG. 5. Rogers Mountain, near Zindel.

portation. Similar deposits on the Idaho side of the river are being opened up preparatory to utilization.

BENTON COUNTY.

GENERAL STATEMENT.

This county is situated within the great low plain of Columbia river. The only localities where the plain verges into plateaus and hills are along the divides south and north of Yakima river. Extending east and west along the general divide between the Yakima on the north and the Columbia on the south is the eastern end of the Horseheaven plateau, which extends from the Cascades to the Columbia. North of Yakima river is a barren plateau which has been partly eroded and which makes up the Rattlesnake hills. Both Yakima and Columbia rivers flow in broad valleys with extensive flats along them. There are not many places where the bedrock appears at the surface, and such localities are generally along the streams where low cliffs occur. Practically the whole county is covered with a thick mantle of soil, which becomes more and more sandy in descending from the plateaus to the lowlands.

The rainfall of the county is low, being everywhere less than ten inches per annum, unless this amount is exceeded upon some of the higher portions of the plateaus. Agriculture, except for the raising of wheat upon the highest levels, is impossible without irrigation. Several systems of irrigation have been already installed, as at Hanford, Richland, Kennewick, Hover and other points along Columbia river. In the course of time a large portion of the county will be under irrigation and it will hence support a large population. Road building as yet has received but little attention, but the time is not far distant when a complex system of roads must be planned and constructed throughout the irrigated districts. The transportation problem for Benton county is a simple one because of the several lines of railway now built and projected, and because of the navigable waters of the Columbia which border the county upon three sides.

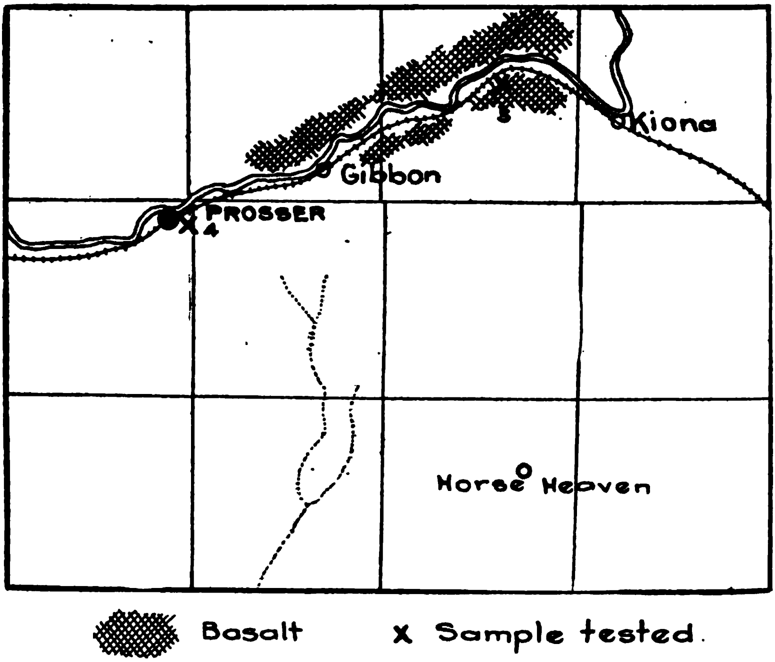


FIG. 6. Central part of Benton county.
Scale, 1 inch equals 6 miles.

The bed-rock of the county is made up of two kinds, viz., basalt, which is much the more common, and some beds of shales and sandstones which form a portion of the Ellensburg formation. The basalt outcrops in the form of bold cliffs along the Columbia on the southeastern margin of the county, and also as lower cliffs along the Yakima below Prosser. The shales and sandstones above noted occur mostly in the northern part of the county where they are generally buried beneath a deep covering of soil. The road materials of the county are confined practically to the basalt and to the deposits of gravel which occur more or less abundantly along Columbia and Yakima rivers. In many instances the basalt is too light and porous to be of value when it is made into crushed rock. Care must be made in selecting a quarry site to find a locality where the basalt is dense and compact and as free as possible from steam holes. In some instances where beds of boulders occur, along the streams it may be practicable to crush these for macadam purposes and in this way derive material which is inexpensive and at the same time desirable.

ROAD MATERIALS TESTED.

Serial Number 4.

Immediately south of the county road, and three-fourths of a mile east of Prosser, is a tract of three acres, owned by the county, on which occurs rounded waterworn pebbles and boulders of basalt of all sizes up to twenty-four inches in diameter. At this point the county authorities have installed a crusher, traction engine and bunkers. About two feet of over-burden has been stripped away. The coarse gravel is dug out with scrapers, run through the crusher, and elevated to the screen where it is sized before it falls into the bunkers. The crushed rock is dense, fine-grained, gray black basalt. It is a hard rock with high resistance to wear, rather low toughness and good cementing value. For all ordinary uses it should make a very good road material. This rock is now being used on macadam construction on the highway running east from Prosser .

Serial Number 5.

At a point about three and one-half miles west of Kiona, between the wagon road and the railway, several ledges of basalt are exposed along the slope. There are occasional cliffs reaching a height of twenty-five feet. At the foot of each cliff there is much broken rock, but as a rule very little soil. Immediately north of pole number 467 of the Yakima Power Company there is a little cliff of basalt, about twenty-five feet high and several hundred feet long. The freshly broken rock has a gray-black color, is very fine-grained, very hard, and breaks with a conchoidal fracture and sharp splintery edges. The ledge appears to have been a part of one lava flow, and is fairly uniform, though the abundance of steam holes varies somewhat. A sample was taken from the north side of the base of the little cliff north of pole No. 467, above mentioned. This cliff is about 1,000 feet south of, and 200 feet above, the Northern Pacific track. Ledges of similar rock are exposed at intervals down the slope to the track. The sample when tested in the laboratory ran high in hardness, toughness, and resistance to wear. The rock has a good cementing value and should make a very good road material.

There is much rock exposed along the railway between Gibbon and Kiona, but very little between Prosser and Gibbon. The largest and best exposed of the accessible outcrops occur on the north side of Yakima river along the new line of the North Coast railway. On the south side of the river the largest cliffs and longest talus slopes are found along the break of the summit of the adjacent plateau, hundreds of feet above, and at some distance to the south of the Northern Pacific railway.

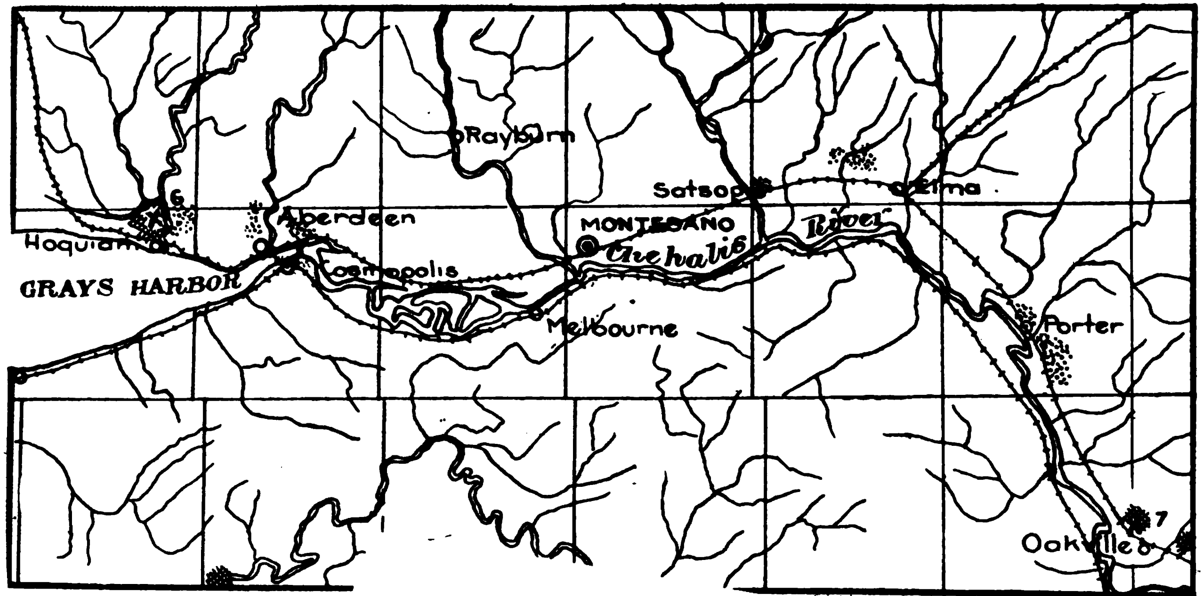
A county road parallels the Northern Pacific railway the entire distance from Prosser to Kiona, which at no point is over one-half mile from the railway. For the major portion of the way it is above the railway, and along it there are some rather steep grades. All the rock exposed along the railway and county road is basalt, except at a locality one mile east of Prosser, on the south side of the highway, where there is a little quarry in another kind of rock. The rock is a soft, light-colored tuff (Ellensburg formation), with a low specific gravity, and occurring in horizontal beds. The basalt along the railway, and between it and the highway, is dark in color, rather hard, and varying much in the percentage of steam holes. Along portions of the way the basalt occurs in low cliffs, and is a weathered, rusty-looking, rough-surfaced, pitted rock. There is much broken rock on the surface of the slopes, with very little or no soil at all. Along Yakima river, and sometimes above the railway as well, there are benches of stream gravels, composed of waterworn basalt pebbles.

CHEHALIS COUNTY.

GENERAL STATEMENT.

This county has a long frontage on the Pacific ocean, and extends inland from 35 to 50 miles. The county is crossed from east to west by the wide valley of Chehalis river, which has its mouth in the broad tidal estuary known as Grays Harbor. South of the Chehalis the interstream divides constitute chains of low hills; north of the river the country rises gradually until the higher Olympic mountains are reached along the northern margin of the county. Only the latter part of the county contains any considerable areas which are too rough and broken to be utilized agriculturally when the time comes to develop the land for such purposes. The bottom lands have an excellent soil and are capable of supporting a large population.

The rainfall of the county ranges from 60 inches to over 100 inches per year. As a result of the high precipitation and comparatively uniform temperature, the vegetation grows with great luxuriance. All the county is densely wooded, except for a few very small tracts where the soil is mainly coarse gravel. Lumbering has been for some years, and is now, the chief industry of the county. In time the logged-off lands will be replaced by farms, and then a complete system of highways will be necessary. At present the chief roads connect only the larger towns along Chehalis river, and these with the ocean at Moclips. Where the precipitation is so great much care must be taken in grading and draining the roads in order to prevent an almost constant muddy condition.



▨ Basalt

Scale, 1 inch equals 6 miles.

bed-rock of the county consists almost wholly of a series
les and sandstones, with outcrops of basalt at rare in-
. The soil has been very largely made by the weathering
above rocks, and hence is mainly a sandy clay, with a
rable amount of humus derived from decaying vegetal
. Along the streams, especially the Chehalis, there are
terraces largely composed of gravel. For some miles
from the ocean beds of gravel are abundant in the
and along the hillsides. These are of marine origin and
posited when the sea covered this portion of the county.
terials suitable for road building are to be had chiefly
asalt ledges and from the gravel deposits. The basalt
far been used only as a crushed rock for certain street
he gravel beds have been used on several of the highways.
ain county road down the Chehalis valley from Oakville
rdeen and Hoquiam has recently been graveled. The
etween Hoquiam and London has been covered part way
shed rock and the remainder of the way by gravel.
. is now being placed on the highway from London to
ach at Copalis. The gravel deposits are mainly com-
of waterworn sandstone or quartzite pebbles, which are
lly reddish in color. The gravel seems to bind fairly
n the roads, probably due to the large amount of oxide
n present. The highways surfaced with gravel are quite
satisfactory where the traffic is not too heavy.

ROAD MATERIALS TESTED.

Serial Number 6.

Immediately north of Hoquiam is a small basalt quarry owned by the city. It is about one-fourth mile north of the intersection of Lincoln street and the Northern Pacific track. Lincoln street passes the eastern end of the quarry. The quarry is located on the side of a small knob, which is an outlier of a large ridge immediately to the west. The knob has a diameter of about 200 feet, and is about 70 feet high. It consists of a mass of broken and in part weathered basalt, with practically no soil covering. The core of the knob or smaller hill is made up of basalt which is very much broken and is so soft that it has been found useless for surfacing streets. The overlying basalt of the knob is very hard and compact, dark in color, and breaks with a shell-like fracture. It makes up about one-third of the entire mass and is now the only rock quarried and used. A sample of this rock was collected and tested. It runs high in hardness, toughness, and resistance to wear. It has a good cementing value and as a road material is very good.

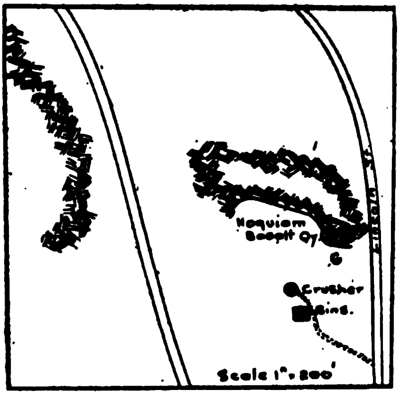


FIG. 7. Location of basalt quarry, near Hoquiam.

At this quarry one of the contractors, Mr. C. Dalk, who is getting out the rock for the city, estimates that there are about 40,000 cubic yards of the good rock left in the knob. A large amount of rock has already been quarried and crushed and used on some of the Hoquiam streets, chiefly on M, U, P, Maple, Olive, Buchanan, Spruce, Lincoln, Polk and other streets. The crusher is operated by electric power; the rock is screened to three sizes.

Between the quarry just described and the larger hill on the west there is a wagon road. On the side of this hill facing the road there is a cliff of fractured basalt very similar to that which is taken out of the quarry noted above. The cliff has a maximum height of 100 feet and is about 750 feet long, with little or no overburden except some residual rock fragments. It is estimated by contractors that there are at least 200,000 cubic yards of basalt in this hill similar to that obtained in the quarry and identical in character to the sample which was tested.

Serial Number 7.

This sample was taken at a point one mile west of Oakville, from a quarry formerly operated by the Northern Pacific railway. The railway company has a spur track to the face of the quarry and used the rock for riprap work. The rock is so broken that it is not very desirable for this purpose. The sample when tested proved to be a dense, fine-grained, dark gray basalt with average hardness, toughness and resistance to wear. It has an excellent cementing value and should be a first class road material. In the quarry the face of rock exposed is about 30 feet high and 300 feet long. The ground back of the quarry is very gently sloping, so that the height of the rock face cannot be very well increased.

CHELAN COUNTY.

GENERAL STATEMENT.

This county is in north-central Washington and extends from the low valley of the Columbia westward to the summit line of the Cascade mountains. A large part of the county is wild and mountainous and possessed of great scenic beauty. In time highways will undoubtedly be constructed into the mountain fastnesses for the scenery involved, but in the immediate future the roads will be limited to the lower valleys.

In the mountains there is enough precipitation to produce a good forest growth wherever the slopes will retain sufficient soil. In the lowlands the rainfall will not support agriculture, and irrigation must be practiced. In the Wenatchee valley, along the Columbia, about the foot of Lake Chelan, and elsewhere, very important irrigated districts have been undergoing development for a number of years. The remarkable success attained in fruit growing has led to rapid settlement, and the population per square mile in the irrigated valleys will soon be very large. With a large country population there is now the necessity for systems of highways of the best type. In the older irrigated valleys, where the ranches contain from 5 to 10 acres, the highways are used so constantly that they must be kept in first class condition.

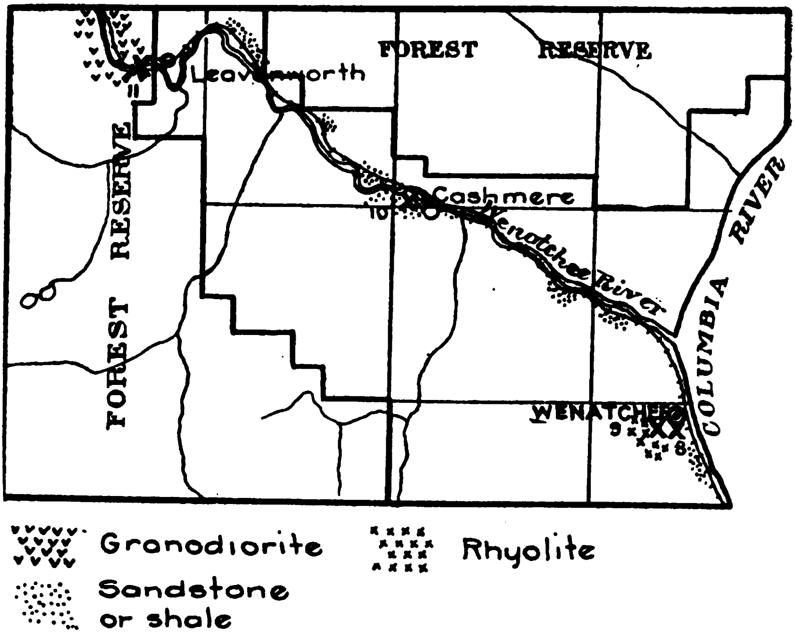


FIG. 8. East central part of Chelan county.
Scale, 1 inch equals 6 miles.

The rock formations of Chelan county are mostly of the crystalline varieties, such as granite, gneiss, and schist. These rocks predominate throughout the northern and western portions of the county. Along the Wenatchee valley from Leavenworth to Columbia river, and also for some miles both north and south of Leavenworth there are broad areas of sandstones and shales, generally tilted at high angles. These rocks are much softer than the granite and related crystallines and hence within them the valleys have been eroded wide and deep and the intervening divides worn down to low ridges. In the southern end of the county a broad plateau of basalt occurs, which is conspicuous along Columbia river, below Malaga. In a general way the crystallines are older than the sandstones and shales, and the basalts are the youngest of them all.

ROAD MATERIALS TESTED.

The basalt noted above is undoubtedly the best road material in the county but it is not easily accessible for transportation by rail or otherwise. The most convenient places to secure basalt are from the cliffs along the east bank of the Columbia in the vicinity of Rock Island. Excellent rock may be had at these places very conveniently located for transportation to Wenatchee and other places in Chelan county where crushed rock may be desired. These localities are described under Douglas county.

Serial Number 8.

For some miles down the valley below Wenatchee very large boulders occur on both sides of the river. They are generally angular in shape and have been carried to their present positions by a great glacier which once came down the Columbia as far as the mouth of Moses coulee. The boulders are generally strewn about promiscuously but are sometimes arranged in ridges or true moraines. In the south end of Wenatchee some of these boulders are from 15 to 20 feet in diameter. The boulders composed of schist break readily into slabs and are generally split up and used in making foundations for houses. Recently rock crushers have been installed and the broken stone used in macadamizing the principal streets of Wenatchee. The samples selected for testing were taken from the loads of crushed rock as they were being placed upon the streets. The results of the test showed that the rock has a low resistance to wear and only a fair cementing value. On city streets where the traffic is heavy such rock is too friable and too easily abraded to be serviceable and its use is not recommended. On such streets only the best kind of rock should be used for surfacing and it is a case where the best is the cheapest.

Serial Number 9.

About two miles southwest of Wenatchee there are some weathered, craggy cliffs of rhyolite. The rhyolite is a dike of igneous rock that has come up through the sandstones and shales. It makes a rather conspicuous ridge along the southwestern rim of the valley, where it projects above the neighboring softer rocks. The rhyolite is grayish-white in color, and is composed essentially of large crystals of quartz, feldspar and mica in a compact groundmass. It splits completely into plates from one-eighth to one-half inch in thickness, and locally is known as "shell-rock." So much of the cliff has flaked off that in several cases there are "chimneys" of rock projecting out of a great mass of loose talus. From time to time the broken, fragmental rock has been hauled out on the adjacent highways for surfacing. The rock is soft and easily worn to powder and from the results of its use it is evidently not a satisfactory road material. The samples taken to be tested proved to be in pieces too small to determine in the laboratory the wear, hardness and toughness. The test showed that the rock has a good cementing value.

Serial Number 10.

About one and three-quarters miles northwest of Cashmere, along the railway track for several hundred feet there is a 50-foot cliff of rock overlaid by from 10 to 25 feet of soil. The formations here are mostly massive sandstones and conglomerates, with a little shale. There are some very narrow bands and pockets of lignite in the different rocks. The sandstone is the hardest as well as most abundant rock, and a sample was taken away for testing. An analysis showed that it contained a large amount of feldspar as well as quartz grains. It has a low resistance to wear but a good cementing value. It is not recommended as a suitable material for macadam construction.

Serial Number 11.

This sample was taken from the foot of the first cliff, along the railway track, at the entrance to the box canyon immediately west of Leavenworth. The rock is a granodiorite, coarse-grained, and composed essentially of plagioclase, orthoclase, hornblende, biotite and quartz. The test showed that it is a hard rock with low toughness and resistance to wear, and is possessed of fair cementing value. It is recommended as suitable only for the foundation course in straight macadam construction.

The granodiorite makes up the canyon walls for several miles north of Leavenworth, as far as Drury. Between Drury and the point where the railway crosses Wenatchee river there is a belt of metamorphic rock, much squeezed, folded, broken and weathered. The rock is principally schist, with occasional bands of serpentine.

Between Chiwaukum and Merritt the valley of Nason creek is broad and bordered by rounded, forested slopes. The only rocks along the railway are a few small ledges of sandstone, conglomerate and shale. From Merritt to Cascade tunnel very much rock is exposed in large cliffs bordering the railway. For the most part the rock is made up of alternating bands or belts of schist and gneiss. At the east portal of the tunnel the rock is a granodiorite similar to that described above as occurring near Leavenworth.

CLALLAM COUNTY.

GENERAL STATEMENT.

Clallam is the extreme northwestern county of the state, and borders on both the Pacific ocean and the Straits of Juan de Fuca. The Olympic mountains cover all the county except the western end and a long narrow strip along the Straits. The rainfall is very large and virtually all parts of the county are heavily forested. Lumbering is the principal occupation and doubtless will continue to be so for many years. The road materials were not studied with care, nor any rock samples taken, because of the little demand for this information at this time. The towns are small, the settlements are remote, and the population of the county not large for the area involved.

The county and state road which is being constructed from Clallam to Forks and southward is well graded, and is surfaced for the most part with gravel. Beds of gravel are convenient all along the way so that pits may be opened so frequently that the length of haul is short. Gravel of good quality for road building seems to be well distributed throughout the western portion of the county and it will be of great value in future road building in that section.

CLARKE COUNTY.

GENERAL STATEMENT.

Clarke county has Columbia river for its southern and western boundaries, and Lewis river for its northern margin. Along the Columbia the country is low; toward the interior of the county it is gently rolling; along the eastern margin one finds the higher foothills of the Cascades. The precipitation ranges

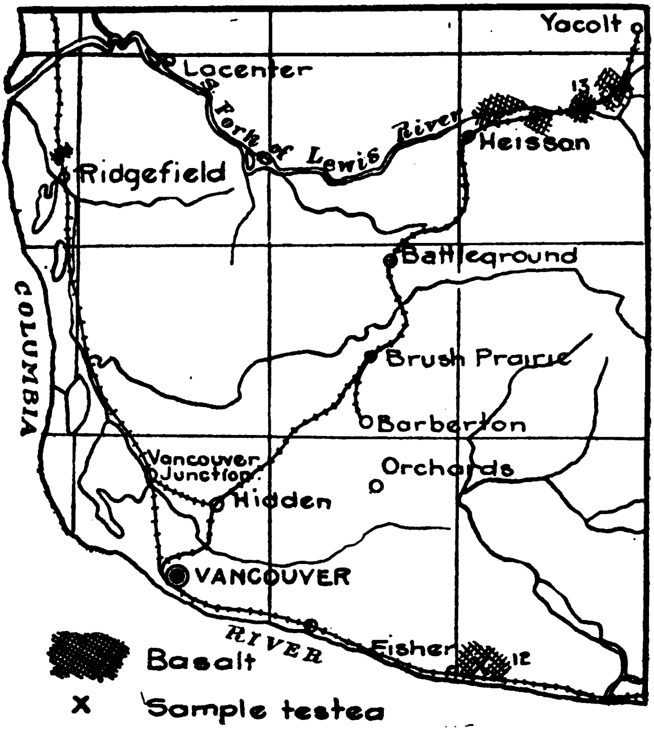


FIG. 9. Southwestern part of Clarke county.
Scale, 1 inch equals 6 miles.

from 45 to 55 inches annually and this insures a heavy forest growth. Lumbering has been a very important industry but agriculture and horticulture have recently become important as well. In general the soil is excellent so that good farms are obtained wherever the forest growth is cleared away.

The bed-rock over a large portion of the county is made up of flows of lava—generally basalt but sometimes andesite. In the lower, level country the bed-rock does not commonly outcrop, but is covered by a deep mantle of soil. Among the hills, and along some streams, ledges of rock are very common. Both the basalt and andesite will usually make good road material when crushed. In addition a certain amount of gravel may be had from the bars along the larger streams. As far as known there are no glacial deposits within the county to supply good material for road surfacing.

Since the farming communities of the county are being rapidly extended a system of good highways must soon be constructed. It will be necessary to use crushed stone in surfacing the main highways of travel. The localities where good rock deposits occur, convenient for transportation, are described below. In addition to these there are without doubt, many others, off the lines of railway, that could be utilized in the building of many of the highways.

ROAD MATERIALS TESTED.

Serial Number 12.

This sample was taken from the large quarry one mile east of Fisher. At this point a quarry, or series of quarries, extends for about 800 yards along the hillside. The bluff, located a little way from the river bank, has a general height of about 200 feet. The quarry faces are low, situated as they are near the crest of the bluff, so that the rock is removed and loaded into river barges by a gravity system. The rock occurs for the most part in large columns and is easily quarried. The amount of material available here is very great. Its principal use thus far has been in the building of riprap, jetties, and similar construction work. Large quantities of this rock have been used on the Fort Stevens jetty at the mouth of the Columbia.

walls of the deeper valleys. Very high cliffs of basalt may be seen along the south side of Snake river, both above and below Riparia. The sides of Touchet river valley, from Dayton to Huntsville, are walled with basalt, very conveniently located for transportation. Outcrops of rock are very rare in the interstream areas, where a deep covering of soil has accumulated. Not all of the basalt is desirable for road building. Much of it is filled with steam holes, and is therefore very slaggy and porous. The wearing quality of such rock is too low for it to be used in macadam work. It is always possible to find sufficient deposits of the better class of rock so that the inferior basalt need not be drawn upon.

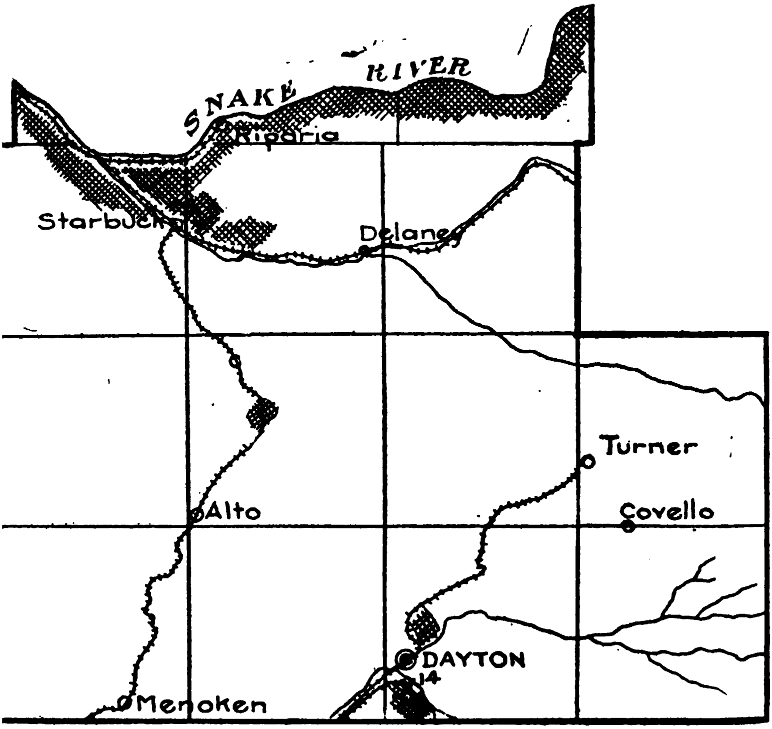


Fig. 11. Northern part of Columbia county.
Scale, 1 inch equals 6 miles.

ROAD MATERIALS TESTED.

Serial Number 14.

Immediately south of the limits of Dayton, along Touchet river, there is a basalt cliff from 300 to 400 feet high, and over half a mile in length. The rock is basalt, made up of several flows, arranged in horizontal layers. The rock is very fresh and unweathered, and but a small thickness of soil caps the basalt hill. In some portions of the great rock mass there are too many small cavities to make the stone valuable as a road material. But at other points large quantities of rock occur that are very dense and compact and which may be utilized in macadam work. The cliff has such a height that a large crushing plant, using a complete gravity system, could readily be installed. The bunkers might be readily connected with the two lines of railway that come to Dayton, and would also be accessible for wagon haulage as well. From time to time small quarries have been in operation on the small benches on the face of the cliff, and the basalt blocks used about Dayton for foundations and otherwise.

The sample for testing was taken from a small quarry on the top of a low bench, at the end of the cliff nearest Dayton. It represented the compact, dense, dark gray, fine-grained basalt occurring at that point. The test demonstrated that it is a hard, tough rock with high resistance to wear. It is so hard and tough that it has a rather low cementing value, but on the whole it may be ranked as a good road material.

Immediately northeast of Starbuck there is a bold hill of basalt about 350 feet high. It is quite steep and barren of soil covering. It is only a few hundred feet from the railway tracks and hence very accessible for transportation by rail. In the face of the hill three distinct flows of lava are shown. The basal one is about 75 feet thick and is of poor quality; the intermediate one is of about the same thickness, but has only a small number of cavities within it; the upper layer is much thicker than either of the others but it occurs in small distinct columns and is black, fine-grained, and non-porous. A sample of this rock was taken for testing but was lost in shipping to Seattle from Starbuck. From all appearances at the outcrop it would be safe to say that this would make a satisfactory road material.

COWLITZ COUNTY.

GENERAL STATEMENT.

Very much of this county is included within the broad valleys of Columbia and Cowlitz rivers. The central and western portions of the county are made up of flat alluvial bottom lands, bordered by low, irregular, rolling hills; the eastern portion is quite rough and broken, since it extends well into the foothills of the Cascade mountains.

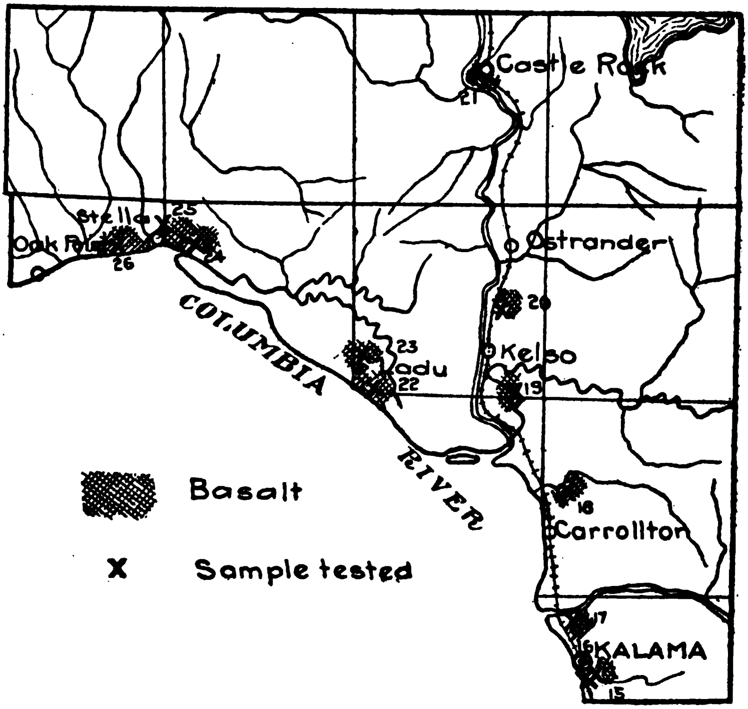


FIG. 12. Southwestern part of Cowlitz county. Scale, 1 inch equals 6 miles.

The annual rainfall of the county is in excess of 60 inches per annum. As a result of this high precipitation and the heavy mantle of soil every portion of the county was originally heavily forested. In all the valley bottoms the forests are giving way to farms. Roads have been under construction for some years and a good system of highways will soon be worked out. The main thoroughfares are those connecting the towns along Cowlitz and Columbia rivers. Because of the high rainfall and flat character of much of the country the proper grading and drainage of the highways are of primary importance.

Both crushed rock and gravel have been used in surfacing the roads. The crushed rock has been taken from the frequent ledges which occur, and the gravel from the numerous bars and benches along the streams. Both south and north of Kalama for short distances the highway has been surfaced with rock. At Carrollton about 1,000 feet of the state aid road has been surfaced with crushed rock which will be used only until something better can be secured. The county road between Kelso and Stella has been treated from time to time with basalt and gravel from deposits along the way. A small portion of the road between Kelso and Ladu has been surfaced with basalt. About one-half mile of the highway from Castle Rock to Silver Lake has been macadamized.

Within Cowlitz county there are two principal varieties of bed-rock, viz., basaltic lavas and some young sedimentary rocks, consisting of sandstones and shales. The sedimentary rocks underlie almost the entire county, but outcrops are not very frequent. At several places they are known to include workable seams of coal, but as a source of road material they are of no value. The basalt occurs in rather frequent dikes or ledges and is very generally of a good character. It is so widespread that it will be of great service in future road building in the county.

ROAD MATERIALS TESTED.

Serial Number 15.

This sample was taken from an old quarry located about three-fourths of a mile south of the Northern Pacific railway station at Kalama. The quarry was once operated by the railway, its owner, the rock being used in rip-rapping. The quarry was opened on the east side of the track in the side of a ridge 50 or more feet in height, where the overburden was slight. The grade for a spur track, several hundred feet long, from quarry to main line, yet remains. The rock is a dark gray, fine-grained basalt free from steam holes except at the highest point in the quarry. The sample was taken from one of the large quarried blocks and the test showed the rock to have average hardness and resistance to wear, with low toughness. It has good cementing value and should make a satisfactory road material.

Serial Number 16.

About one-half mile south of the courthouse at Kalama in SE¼ of Sec. 17, T. 6 N., R. 1 W., on the county road, there is a small quarry which is not now operating. In former years the rock has been crushed and used in surfacing the streets in Kalama, and also the highway running southeast from Kalama. In the quarry a face of rock 10 feet high and 100 feet long has been opened up. There is very little overburden. The rock is a gray black, fine-grained basalt, with a few small steam holes scattered through it. A sample was taken from the quarry face and the test proved the rock to have average hardness and resistance to wear, but with rather low toughness. The test proved it to have good cementing value and it should make a satisfactory road material.

Serial Number 17.

About two miles north of Kalama, immediately south of the intersection of the county road and Kalama river, there is a hill with a steep westerly slope, on which several rock ledges are exposed. This rock is also exposed along the highway, in ledges up to 25 feet in height. A sample was taken from a ledge along the wagon road, at a point not over 100 feet from the railway. In the outcrop the rock appears rather soft but with very few steam holes. When tested the rock proved to be a fine-grained, dark gray basalt with average hardness, toughness and resistance to wear. It has high cementing value and is recommended as an excellent road material.

Serial Number 18.

About one and one-half miles northeast of Carrollton, on Owl creek, basalt is exposed on the county road in low cliffs and ledges. There is a logging road passing by the ledges which would make the rock available for transportation. To the west rock occurs on both sides of the creek, the largest exposure being in the gorge and on the north side of the creek, in cliffs up to 40 feet in height; but the rock on that side is very difficult of access. On the south side of the creek and road there is only about 8 feet in thickness exposed altogether. The overburden is light but the slope is so gentle that a high face of rock could not be secured if a quarry were opened here. A sample was taken at this locality on the south side of the creek and it proved upon testing to be a very dense, fine-grained, dark gray basalt, very hard, with average wearing value and low toughness. It possesses good cementing value and should make a satisfactory road material.

Serial Number 19.

This sample was taken at a point about one and one-half miles southeast of Kelso, in the SE¼ of Sec. 35, T. 8 N., R. 2 W. At this place the county road follows an abandoned railway grade where a cut was once made through a ridge of basalt. On both sides of the road the cliffs, ranging from 10 to 20 feet in height, extend for 300 feet. The rock appears to be somewhat soft, and contains a few tiny steam holes. It is fine-grained in texture and dark greenish gray in color. The test showed it to have medium hardness, with average resistance to wear; low toughness and excellent cementing value. It is recommended in macadam work for light traffic only.

Serial Number 20.

Two miles north of Kelso is a hill the west end of which is known as "Rocky Point." It is 400 feet high, with its steepest side facing west. At present the Northern Pacific railway follows the foot of the hill while the county road goes over the west side. A railway tunnel 900 feet long is being driven through the hill, to get rid of the sharp curve around it. When the tunnel is completed it is expected that the county road will follow the present line of the railway, thus avoiding the steep grade over the hill. There is a face of rock 50 or more feet in height on the west side of the hill adjacent to the present track but the height of this face can be much increased if desired, as the slope is rather steep. The rock at this point is a soft, brittle basalt, rather compact, with very few steam holes, and very much weathered. The basalt which is being brought out of the tunnel, and which is from the center of the hill, is unweathered and fresh. A sample of this was taken, and according to the test it may be regarded as a hard rock with low toughness and average resistance to wear. It has excellent cementing value and should be regarded as a first-class road material.

Serial Number 21.

At the south end of the town of Castle Rock there is a roughly triangular hill which in its maximum dimensions is about 100 feet high and 1,000 feet long. It is bordered on the southwest by Cowlitz river, on the opposite side by the railway tracks and on the north end by the town. The hill is flanked on the river side by beds of alluvium but the remainder of it is basalt, with not much soil on top. The rock is a heavy, compact black basalt free from steam holes. It is very uniform throughout in character. A sample was taken at the northwest end of the hill near the base. The test proved it to be a hard rock with low toughness and average resistance to wear. It has very good cementing properties and should make an excellent road material. Rock has been taken from the hill by both the county and railway for rip-rap work.

Along the Northern Pacific railway, between the crossing of Cowlitz and Toutle rivers, there are several rock cuts in basalt. The largest cut is about 400 feet long and from 10 to 35 feet deep. The rock is dark, compact, and rather soft on the weathered surfaces. Immediately south of the Cowlitz crossing, in the NE¼ of Sec. 16, T. 9 N., R. 2 W., the railway company has been operating a quarry where the rock has been used in rip-rapping. At the quarry a face of basalt has been developed having a length of 500 feet and a maximum height of 40 feet. There is from 1 to 3 feet of overburden. The rock is exposed in a natural cliff from 20 to 50 feet high a few hundred feet southeast of the railway quarry. The rock at the quarry, where a sample was taken, is a dark, fairly hard, compact basalt that breaks with a conchoidal fracture and sharp edges. The sample was lost in shipping and therefore was not tested.

Serial Number 22.

At Ladu there is a small hill 288 feet high and several hundred feet long, known as Mt. Coffin. It is an isolated hill, bordered on one side by Columbia river, and on the other sides by a flat lowland. The hill is a solid mass of basalt, either bare or with a very thin veneer of soil. A quarry has been opened on the river side, where a face has been exposed approximately 400 feet long and 150 feet high. There is much columnar jointing, the columns occurring in fan-shaped sheaves. The rock breaks with a conchoidal fracture, and has a clinking sound. It is very uniform throughout and there is but little waste material. A sample was taken from some rock that had been freshly quarried. According to the laboratory test it is a dense, fine-grained, dark gray basalt, hard and tough, with a high resistance to wear. It shows a good cementing value and on the whole should make an excellent road material.

This property is owned by the Star Sand Company of Portland. They have installed two crushers which have a capacity of 400 tons of crushed rock per day, of one shift. The crushed rock is conveyed to a bin with a capacity of 1,200 tons, and dropped in chutes from the bin to scows below, which have a capacity of 600 tons each. The rock is sold by the company for use in surfacing streets and roads.

Serial Number 23.

About 2 miles north of Ladu there is a 400-foot hill known as Mt. Solo. A county road passes by the foot of the hill on the south side, and along the roadway there are several ledges of basalt outcropping. At one point, in the W½ of Sec. 25, T. 8 N., R. 3 W., there is an outcrop over 100 feet long, with a 15-foot perpendicular face of rock above the talus slope. A sample was taken at this locality, which when tested in the laboratory proved that the rock was a hard basalt with high resistance to wear. It has rather low toughness and fair cementing value and should make a satisfactory road material.

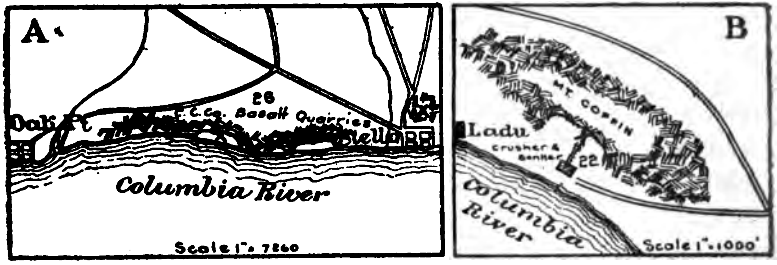


FIG. 13. A—Basalt quarries near Stella. B—Quarry and crusher near Ladu.

Serial Number 24.

About 1 mile east of Stella, on the north side of Coal Creek slough, there is a small hill with a low basalt cliff exposed on the south side. A portion of the rock displays columnar jointing. There are some steam holes, the amount varying from place to place. A sample was taken from the bottom ledge, just north of Snyder's shingle mill. According to the test the rock is a fine-grained, steel gray, very porous basalt. It is hard, possesses average toughness, with high resistance to wear. Although it has low cementing value it should make a satisfactory road material. The property belongs to M. Gorman of Stella. Shipments of rock may be made by way of the slough, which is deep and navigable.

Serial Number 25.

Stella is situated at the foot of a bluff over 250 feet high, facing the river. The face of the bluff is very steep, with several basalt cliffs and much broken rock. The rock is not uniform in character and much of it appears to be poor in quality. There are three phases of the basalt, which grade into each other to some extent, as follows: (1) a soft, spongy-looking, very porous rock; (2) some soft rock with myriads of tiny steam holes; (3) a fairly hard, compact rock, containing a few tiny steam holes. A sample of (3) was secured on the face of the hill about 200 feet above Stella. When tested it proved to have average hardness, toughness, high resistance to wear, and fair cementing value. If the rock is carefully selected in quarrying it should make a satisfactory road material.

Serial Number 26.

Bordering the river between Stella and Oak Point there are almost continuous basalt cliffs from 50 to 150 feet in height, consisting of several different flows. In one cliff 6 distinct flows can readily be distinguished, and in most of them columnar jointing appears. In the upper portion of each lava-flow steam holes are very abundant and the rock too porous to be serviceable. About one-half mile west of Stella is an old quarry once operated by the Cascades Contract Company. The quarry was abandoned on account of the poor quality of the rock. About a mile west of this locality, about half-way between Stella and Oak Point, a new quarry has been opened by the same company. At this place there is a perpendicular rock face of 110 feet rising from the river bank, capped by a terrace, and back of this a second perpendicular face of 50 feet, giving a total drop of 160 feet. A quarry 600 feet long from east to west has been opened on the face of the upper cliff, upon the terrace. The rock from the quarry is a fresh looking, heavy, fine-grained, dark steel gray basalt. It breaks with a perfect conchoidal fracture and sharp edges. It possesses columnar jointing and is free from steam holes. The rock has been used for jetty work at the mouth of the river, and much of it is made into paving blocks which are scowed to Portland, the chief market. A sample was taken from the material used for paving blocks. The laboratory test proved it to be a hard, tough rock with low cementing value. It should make a satisfactory road material, especially for roads with a heavy traffic.

DOUGLAS COUNTY.

GENERAL STATEMENT.

This county lies within the great bend of Columbia river, in the central part of the state. Its surface is that of a plateau, bordered on the northern and western sides by the great gorge of the Columbia, and on the eastern side by Grand coulee. Moses coulee is a deep trench which extends from Columbia river over half-way across the county, running approximately parallel with Grand coulee. The broad plateau of the county has an average elevation of about 3,000 feet above sea level in the northern portion, and descending to about 1,200 feet along the southern margin of the county. Badger mountain runs from east to west across the southern portion of the county. It is an upwarp of the plateau, with broad slopes, and has a maximum elevation of a little more than 4,000 feet.

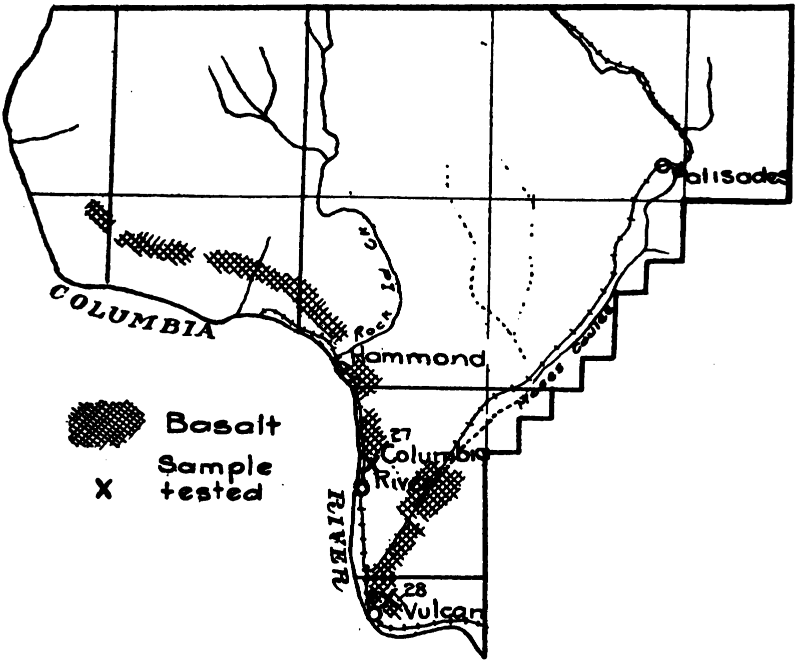


FIG. 14. Southern end of Douglas county.
Scale, 1 inch equals 6 miles.

Douglas county has basalt for its bed-rock everywhere except for a small area of sandstones and shales along the southern margin opposite Wenatchee, and for a narrow fringe of granite and related rocks which lie at the base of the canyon walls along the Columbia, principally from the vicinity of Orondo northward. The only material suitable for road building is basalt, but on the uplands this is covered by a heavy mantle of soil. Along the deeper ravines and coulee walls the basalt, often in palisades or cliffs of columnar rock, appears in enormous quantities. The greater portion of it is very porous and in some instances as full of steam holes as pumice. In securing material suitable for surfacing care must be taken to select those parts of the lava beds where the rock is most compact and fine-grained, and free from steam holes.

This county has a rainfall varying from 8 to 15 inches. The vegetation shows the influence of the range in rainfall, since a sparse forest growth covers the higher Badger mountains, bunch grass is the ruling plant upon the plateaus, and sage brush the principal plant along the bottoms of the deep valleys. While wheat is grown in all of the arable country of the plateau, fruit raising by means of irrigation is coming to be the chief industry of the valleys. Along the benches of the Columbia and throughout Moses coulee many people are making their homes and in these localities systems of highways will soon be a necessity. Whenever macadam roads are constructed a sufficient supply of good material will be easily available.

ROAD MATERIALS.

Serial Number 27.

Along Columbia river in the vicinity of Rock Island station (Hammond P. O.) and below there occur probably the largest and most spectacular basalt cliffs to be found in the state. For miles along the way huge beetling cliffs of columnar rock, hundreds of feet high, tower above the railway track which margins the river. Similar cliffs of basalt occur on the opposite side of the Columbia, and make up the perpendicular walls of Moses coulee as well. For several miles west, and then north, of Trinidad, great deposits of gravel and sand occur adjacent to the railway, forming huge benches. But from a mile north of Columbia River station to Rock Island, where the river is crossed, the track skirts the foot of the great basalt cliffs. A sample was taken from the broken rock at the foot of the tall cliffs near the railway track, about one and one-half miles north of Columbia River station, a very little way beyond the north portal of tunnel No. 12. Columnar jointing is splendidly exhibited in the cliff above, which rises for hundreds of feet. Steam holes vary in the rock from place to place, and the sample was taken where they appeared to be fewest in number. When tested in the laboratory the rock was demonstrated to be a dense, fine-grained, gray black basalt, very hard. It has fair cementing value, and should make a satisfactory road material.

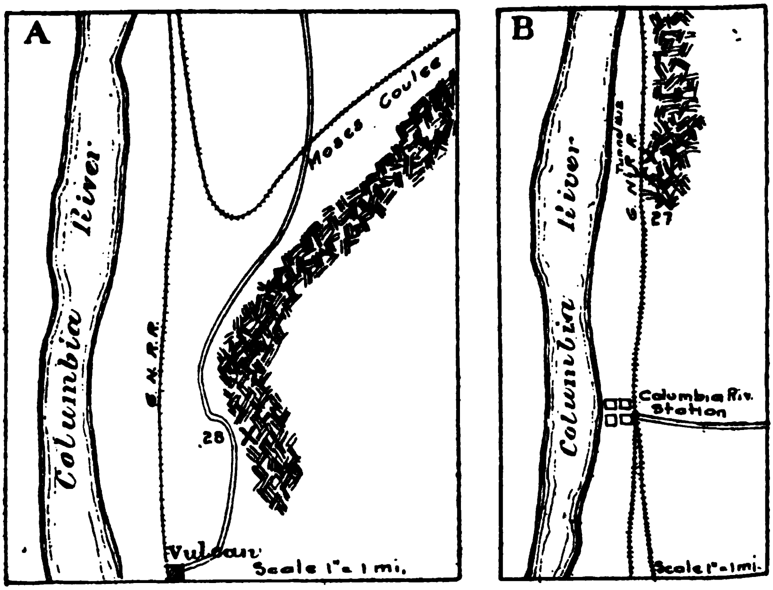


FIG. 15. A—Basalt ledges near Vulcan. B—Cliffs near Columbia river station.

Serial Number 28.

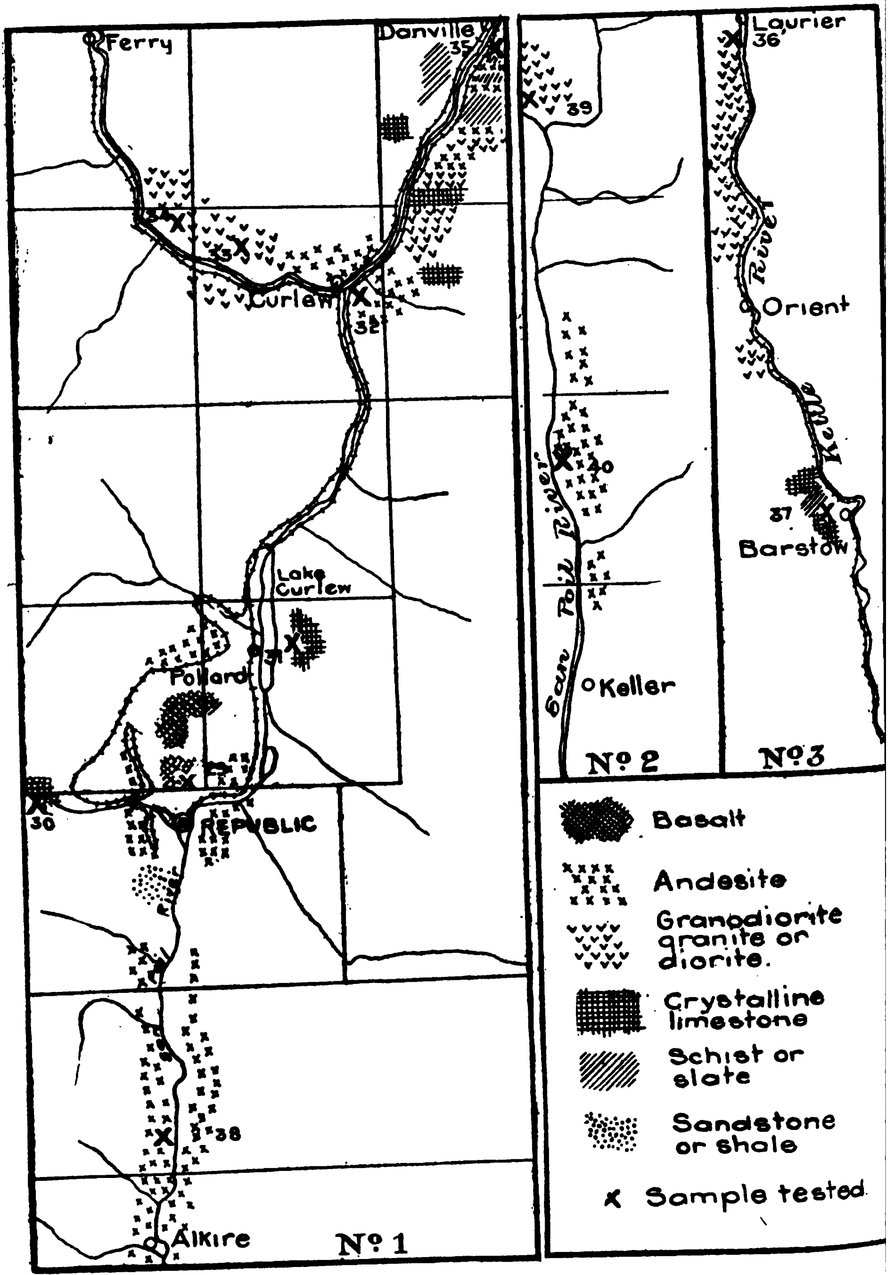
This sample was taken from the broken rock at the foot of a tall cliff on the D. K. Smith ranch, nearly a mile northeast of Vulcan, about 3½ miles from Columbia River station. The foot of the cliff is half a mile east of the railway, and about 200 feet above it. Gravel benches parallel the railway between it and the cliff. The latter has an almost perpendicular face several hundred feet high, and appears to consist of six different flows. In the bases of two of the flows rounded pebbles are enclosed. The cliff displays columnar jointing on a large scale, the columns occupying almost all positions from perpendicular to horizontal, and occurring in some instances in fan-shaped sheaves. When tested the rock was found to be a fine-grained, gray black basalt, hard and tough. It has a high resistance to wear and fair cementing value. It breaks with a shell-like fracture, is rather free from steam holes, and should make a satisfactory road material. The same conclusions may be drawn regarding all the rock along the cliff for a mile north of this point.

FERRY COUNTY.

GENERAL STATEMENT.

This is in general a mountainous county, the principal exceptions being the broad valleys of Columbia, Kettle and San Poil rivers and Curlew creek. The mountains as a rule have rounded forms and gentle slopes. The soil is rather deep and rock cliffs comparatively infrequent. A great variety of rocks occurs, among them being andesite, granite, basalt, sandstone, limestone, schist and slate. Rocks suitable for road materials are widespread and no long hauls will be necessary in constructing macadam roads. Besides the bed-rock there is much gravel accessible for road use. All the larger valleys are bordered by extensive terraces of sand and gravel of glacial origin.

The annual rainfall of the county varies from 10 to 20 inches. A forest covers practically all of the county except the more arid lowlands of the deeper valleys. The trees do not grow close together, and there is a general absence of shrubbery as an undergrowth. Grasses and flowers grow among the trees so that the whole country takes on a distinctly park-like appearance. The economic development so far has not led to



No. 1—Along the upper San Poil and Curlew valleys.
No. 2—Along the lower San Poil river.
No. 3—From Laurier to the mouth of Kettle river.

Scale, 1 inch equals 6 miles.

the establishment of thickly settled communities, so that there has been little necessity for the best type of highways. The towns and agricultural districts are confined to the larger valleys, and the few roads of the present time run mainly within and parallel to the valleys.

ROAD MATERIALS TESTED.

Serial Number 29.

Beginning at a point a mile north of Republic is the south end of a very irregular area of basalt, covering in all approximately two square miles. The rock is best exposed not far from the southeast corner of the basalt area, in the NW¼ of Sec. 36, T. 37 N., R. 32 E., and about one and one-half miles north of Republic. At this point there is a cliff several hundred feet long with a perpendicular face from 30 to 100 feet or more in height, and a slope of broken stone at the base. A wagon road skirts the cliff, connecting with the main highway to Republic. The rock possesses columnar jointing to an unusual degree, and is further cut by small irregular fractures along which it splits readily. There is much iron stain in the larger fractures and on the weathered faces but alteration has not penetrated very far into the rock itself. Very little overburden occurs on the top of the outcrop.

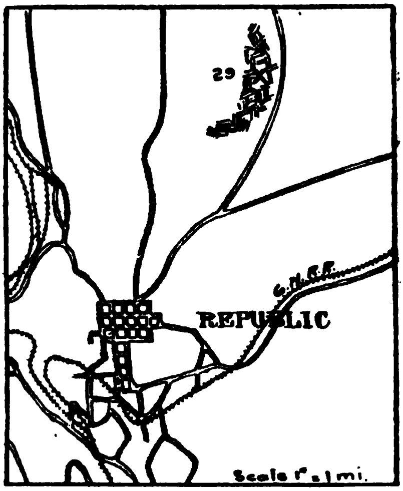


FIG. 16. Basalt outcrop near Republic.

A sample was taken from the broken rock near the north end of the cliff. The fresh rock is black, heavy, compact, brittle, and very hard. It breaks with a sub-conchoidal fracture, leaving sharp splintery edges, and appears to be entirely free from steam holes. The test showed that the rock has low resistance to wear and low cementing power. It is best suited for roads subjected to light traffic.

There is another basalt area covering only a few acres in the eastern part of Republic; besides which a few small basalt dikes occur round about the town.

Serial Number 30.

Five miles west of Republic, on the west fork of Granite creek, there is a small limestone area projecting through the mantle rock. The limestone occurs as cliffs on the south side of the ravine, having a vertical section all told of about 125 feet. Henry Bird, of Republic, the owner of the land, operates a small quarry and lime-kiln near the county road which runs to Republic. The rock is a dense, compact, finely crystalline limestone with a color prevailingly grayish blue, though sometimes white, and occasionally mottled blue and white. It occurs in a massive form and all bedding planes have disappeared. The sample taken from the quarry when tested proved to have average hardness with very low resistance to wear and very low toughness. While it has fair cementing value it is too soft for the construction of any roads, except those having very light traffic.

Serial Number 31.

On the east side of Curlew lake, across from Pollard, there is a limestone area of one-half square mile or more. The ledges form occasional step-like outcrops on the hillside, beginning at a point about 300 feet above the lake. The highest exposure of the limestone is at least 800 feet above the lowest. The soil covering appears to be thin. The rock is an impure limestone of a dark grayish blue color. A sample was taken from a ledge in the NE¼ of Sec. 9, T. 37 N., R. 33 E. When tested in the laboratory it was found to have average hardness, low resistance to wear and low toughness, and good cementing value. It is suitable only for roads having light traffic.

Serial Number 32.

Immediately around Curlew the rock is an altered andesite. The rock has usually a compact groundmass, varying in color through bluish gray and dark gray to a lilac color. Within the groundmass are crystals of feldspar and black mica, giving the rock a mottled appearance. The ledges of rock are cut by numerous joints and fractures. There are some small railway cuts in the andesite within the town of Curlew. A sample was taken from one of these cuts about 200 feet south of the Great Northern railway station. The laboratory test proved the rock to be rather hard, with average toughness and resistance to wear. It has excellent cementing value and should make a very desirable road material.

Serial Number 33.

Four miles west of Curlew the highway has been blasted through rock for about 200 feet, giving a sheer face of at least 25 feet. The rock is fine-grained, with a slightly schistose character. A sample was collected and tested with the following results: The rock is a dark gray diorite of average hardness and resistance to wear, low toughness and good cementing value. It should make a satisfactory road material.

Serial Number 34.

About 7 miles west of Curlew, on the northeast side of Kettle valley, there is a long granite cliff with a steep face at least 250 feet high. The base of the cliff is only 200 feet from the wagon road. It is about 1,000 feet from the railway, with Kettle river between. A sample was taken from the broken rock at the foot of the cliff. According to the test it is a granite rock, made up chiefly of quartz, feldspar and mica. It is a hard rock, with average resistance to wear, low toughness, and fair cementing value. It is not recommended as a road material.

For some miles along the Kettle valley, in the vicinity of the last mentioned locality, there are almost continuous exposures of granite, with occasional belts of schist. Cliffs are very common with faces varying from 20 to 500 feet in height. In general the granite is light in color, except when it is made dark by excess of black mica. Frequent pegmatite veins cut the granite, varying from one inch to one foot in thickness, consisting mainly of pink orthoclase feldspar.

Between Curlew and Danville rock outcrops occur very frequently along the two lines of railway. Northeast of Curlew, on the left bank of the river, both andesite and granite are found, until just beyond Rincon creek where ledges of limestone crop out on the hillside. There is also a small railway cut in the limestone. A sample was taken here which upon testing proved to have but little merit as road material.

Along the Great Northern railway for the first one and one-half miles after leaving Curlew the rock is andesite. From Deer creek to Lime creek, about one mile, there are small cuts in granite. From the latter stream to Skiffington creek, limestone is the country rock with abundant intrusions of granite. The granite is so abundant that the limestone appears in belts separated by the former. There is a large area of limestone on Drummer mountain the outcrops of which can be seen from some distance away. From Hurlburt to the International boundary there are cuts and small exposed ledges of schists and slates, with frequent intrusions of granite and porphyry. At a point about one and one-half miles southwest of Danville there is a great deal of serpentine in the rock cut. A sample was collected here and tested. While the rock has a high cementing value, it is not recommended as a satisfactory road material.

Serial Number 35.

This sample was taken from a cut on the Great Northern railway one mile south of Danville. At this point there is a 10-foot cut in a fine-grained greenish rock which is also exposed on the hillside above. A sample was collected from the south side of the cut. The laboratory examination proved it to be an altered andesite. It is a hard, fairly tough rock, with rather high resistance to wear, and good cementing value. It should make a satisfactory road material.

Serial Number 36.

About three-fourths of a mile south of Laurier, west of the railway, there is a steep bluff at least 1,000 feet high and affording an enormous amount of rock. It is fronted by a cliff with an almost perpendicular face, with its base from 300 to 600 feet from the railway track. The rock has in general a granitoid texture, except where the black mica occurs in excess, which gives the rock a schistose appearance. Pegmatite veins are common, made up mostly of coarse orthoclase crystals of feldspar. A sample was taken from a locality where the rock was a typical granite. When tested it proved to be a hard rock with low toughness and resistance to wear. It has low cementing value and is valueless as a road material.

For some miles southward from the above locality there is an almost continuous line of granite cliffs on the west side of the railway. The cliffs vary from 400 to 1,000 feet in height, with bases from 200 feet to one-half mile from the track. There are numerous railway cuts from 4 to 30 feet in depth. Sometimes the rock takes on a schistose or gneissic appearance, and varies from very light to very dark in color, depending upon the mineral constituents.

Serial Number 37.

Near Barstow where the steel wagon bridge crosses Kettle river the valley is about one-half mile wide. On the east side of the river is a hill at least 700 feet high with a steep westerly slope, on which several limestone ledges occur. On the west side of the valley is a bluff about 400 feet high, with a perpendicular rock face 150 feet or more in height. A steep slope of broken rock extends from the cliff almost to the railway track. The rock varies from a compact blue gray limestone to a light-colored marble. A test was made in the laboratory of the marble selected at this locality. The rock has average hardness, very low toughness, low resistance to wear and fair cementing value. If used as a road material it should be only upon roads having a light traffic.

Serial Number 38.

From Republic southward along the San Poil valley the country rock for the first 10 or 12 miles is andesite. Between the tenth and eleventh mile posts there is an almost continuous cliff of this rock from 300 feet to 500 feet high, with a great talus slope between the cliff and the highway. At a point 10½ miles south of Republic, or 3 miles north of Alkire, the andesite cliff reaches a height of 500 feet, with much of the rock in prominent columns. A sample was taken from the great broken blocks at the foot of the cliff. According to the test the rock is a hornblende andesite, with crystals of augite, plagioclase and hornblende in a dark groundmass. It has low resistance to wear and good cementing value. On roads subject to light traffic the rock should make a satisfactory material for surfacing.

Serial Number 39.

About 14 miles south of Alkire a spur of the mountain, known as the "Devil's Elbow," projects into the valley. The highway crosses this spur for a portion of the way through rock cuts. A short distance east of the road there is a granite cliff several hundred feet high, with frequent outcrops between it and the road. A sample of unweathered rock was taken from one of the cuts along the highway. The test disclosed it to be a granodiorite, coarse grained, light gray, with a faint pinkish color. It is a hard rock with rather low toughness, average resistance to wear, and fine cementing value. It is suitable only for the foundation course in plain macadam construction.

Serial Number 40.

At a point 8½ miles north of Keller, and 41½ miles south of Republic, the roadway has been cut through some ledges of dark gray rock. Immediately east of the road is a cliff, and beyond a series of cliffs, which give a vertical section of at least 250 feet of the same kind of rock. A sample, taken from a ledge by the roadside, was found upon testing in the laboratory to be an altered hornblende andesite. It is a hard rock with low toughness, average resistance to wear, and excellent cementing value. It should make a good road material.

FRANKLIN COUNTY.

GENERAL STATEMENT.

This county is roughly triangular in outline, two sides of it being formed by Columbia and Snake rivers. The whole county slopes gently from the north and east toward the two rivers. At the confluence of the Columbia and the Snake the banks of both streams are very low and composed of alluvial deposits. Along the northwestern margin of the county the Columbia is bordered by cliffs, known as the "White Bluffs," which rise above the water level to heights of 300 to 400 feet.

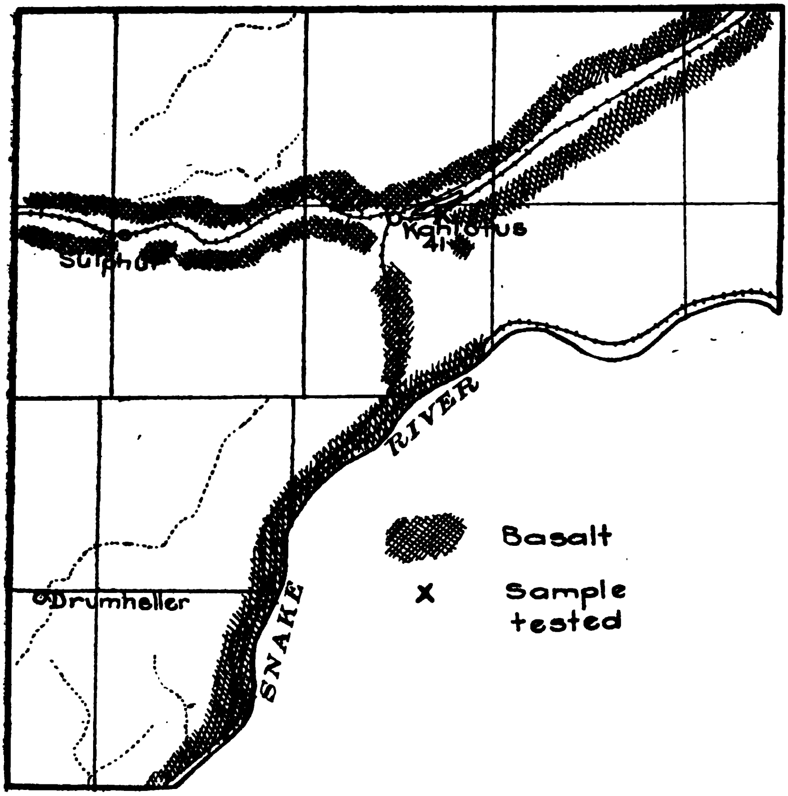


FIG. 17. Southeastern part of Franklin county.
Scale, 1 inch equals 6 miles.

Toward the eastern margin of the county the Snake becomes entrenched in the great lava plateaus, and is bordered by cliffs several hundred feet in height.

A thick deposit of soil and mantle rock covers most of the county. The chief exceptions are the floors and bordering walls of some of the coulees, and the cliffs along the rivers. In the western part of the county, underneath the soil, there are layers of shales and sandstones which have originated in large lakes. Some of these sediments show that they were ashes, cinders and similar light materials at one time ejected from volcanoes. The bed-rock of the eastern part of the county, as seen along Snake river and its small tributaries, is all basalt. The basalt occurs in great broad sheets, representing individual lava flows. The central part of each lava sheet, as seen in a vertical section, is usually dense, compact, and sufficiently free from steam holes to make good road material. The rock toward the lower and upper surfaces of each lava sheet is usually so full of steam holes that it is very porous and sometimes even resembles pumice. When in this condition the basalt is of no value in road construction. In some of the coulees, and along the banks of the rivers, there are beds of gravel which might be used in surfacing the roads where the travel is light.

The rainfall of Franklin county is so low that agriculture is rarely profitable without irrigation. Plans to irrigate certain sections of the county are now under way and this will largely increase the population. The public highways are but little traveled at the present time and the demand for macadam roads has not yet been felt. The dirt roads are very dusty in summer but do not become very muddy in winter because of the large percentage of sand in the soil.

ROAD MATERIALS TESTED.

Serial Number 41.

This sample was taken from the basalt cliff about three-fourths of a mile east of the Spokane, Portland and Seattle railway at Kahlotus. At this point the railway passes between the foot of the cliff and the south shore of Lake Washtucna.

The cliff is made of two flows of compact black basalt, separated by a few feet of very porous and worthless rock. Vertical columns of the lava are very distinct and prominent, some of them being as much as four feet in diameter. There is a good opportunity here for a rock crusher, ample room being afforded for buildings, side tracks, etc., between the cliff and the railway track. The sample when tested in the laboratory proved itself to be a fine-grained, gray-black basalt. It is a hard rock with average toughness, high resistance to wear, and low cementing value. Taking all the properties of the rock into consideration it should make a satisfactory road material.

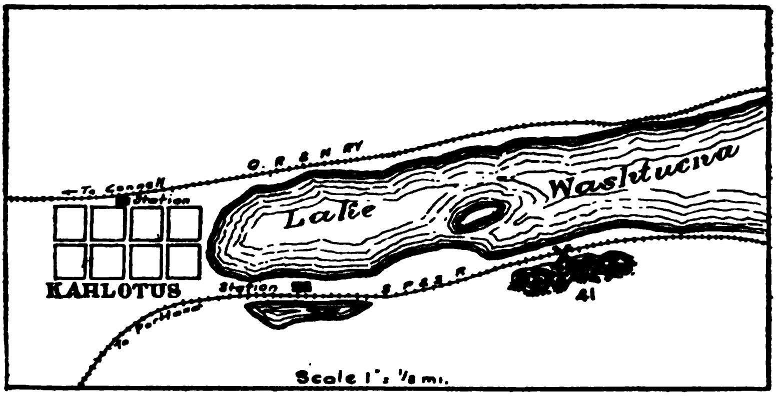


FIG. 18. Basalt cliff near Kahlotus.

Immediately after leaving Kahlotus the Spokane, Portland and Seattle railway passes by tunnel through a high basalt hill and emerges at the head of Devil's canyon. The railway follows the west wall of the canyon down to Snake river. Along the way perpendicular cliffs 300 feet in height rise above the track. On the east side of the canyon is the odd Devil's Monument, a bare pile of rock which rises possibly 400 feet above the canyon floor. Both canyon walls are composed of an excellent grade of columnar basalt. It would be a difficult thing to quarry the rock owing to the precipitous nature of the high cliffs and the lack of room at the base. The best cliffs are about 3¾ miles south of Kahlotus.

From Kahlotus westward along the track of the Oregon and Washington Railway and Navigation Company cliffs of basalt occasionally occur along the coulee walls. The better basalt is found in columnar form, usually making up the topmost part of a cliff, and bordered by a slope of broken rock. Along the south and southeast sides of Sulphur Lake there is such a cliff from 80 to 100 feet in height. The rock is very hard and compact, with a slight overburden of soil and broken rock.

GARFIELD COUNTY.

GENERAL STATEMENT.

Garfield county is a broad plateau, into which the canyons of Snake river, Pataha river, Deadman creek, and those of the Blue mountains have been incised. The southern end of the county, embraced within the Blue mountains, has been so cut up by the erosive work of streams that it abounds in strong contrasts between the deep sinuous valleys and sharp serrate mountain ridges. In the northern portion of the county the uplands comprise a rolling plateau, almost every portion of which is tillable.

The natural rainfall of the county is sufficient in the higher southern portion of the county to support a forest growth, about all of which is contained within the Wenaha Forest Reserve. Throughout the northern portion of the county the bunch grass once grew, but this has almost wholly given way to wheat fields. Agriculture, chiefly in the form of wheat growing, is the greatest industry of the county. On the benches along Snake river, where irrigation is practiced, much early fruit is raised. The towns are practically all located within the valleys; the population of the uplands is sparse because of the fact that the farms are large. But little attention has yet been paid to permanent highways, but for street work and the main thoroughfares some knowledge of the whereabouts of proper surfacing material will soon be imperative.

Over the whole of Garfield county basalt was once the prevailing rock. It accumulated through a long time by the piling up of lava sheets one upon another. In any great canyon wall, as along the Snake, several of these flows may be seen as they lie there in a flat position. In some of the deeper canyons, especially in localities where the overlying basalt was originally thinner than elsewhere, the underlying rock has been encountered. This old floor, as far as it has been discovered in this county, is granite. Granite is known to occur along the Snake at one or more localities and in the valley of Deadman creek.

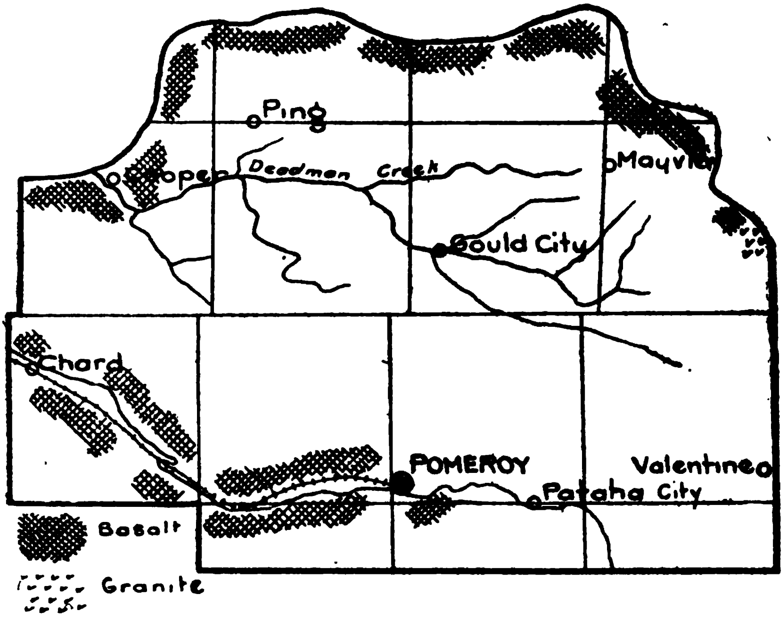


FIG. 19. Northern part of Garfield county.
Scale, 1 inch equals 6 miles.

The most accessible road material in the county, and the locality where it will be earliest needed, is along the Pataha valley from Chard to Pataha City. In the main the rock which makes up the walls of this valley is a very porous basalt, weathered to a brownish color. Practically everywhere the cliffs are low, the rock very brittle, and good road material rather rare. The best rock in the valley is between Pomeroy and Pataha

City. No samples were taken for testing because of its poor quality. Some of the rock might be used for roads having a light traffic, but no rock of the very best quality was found.

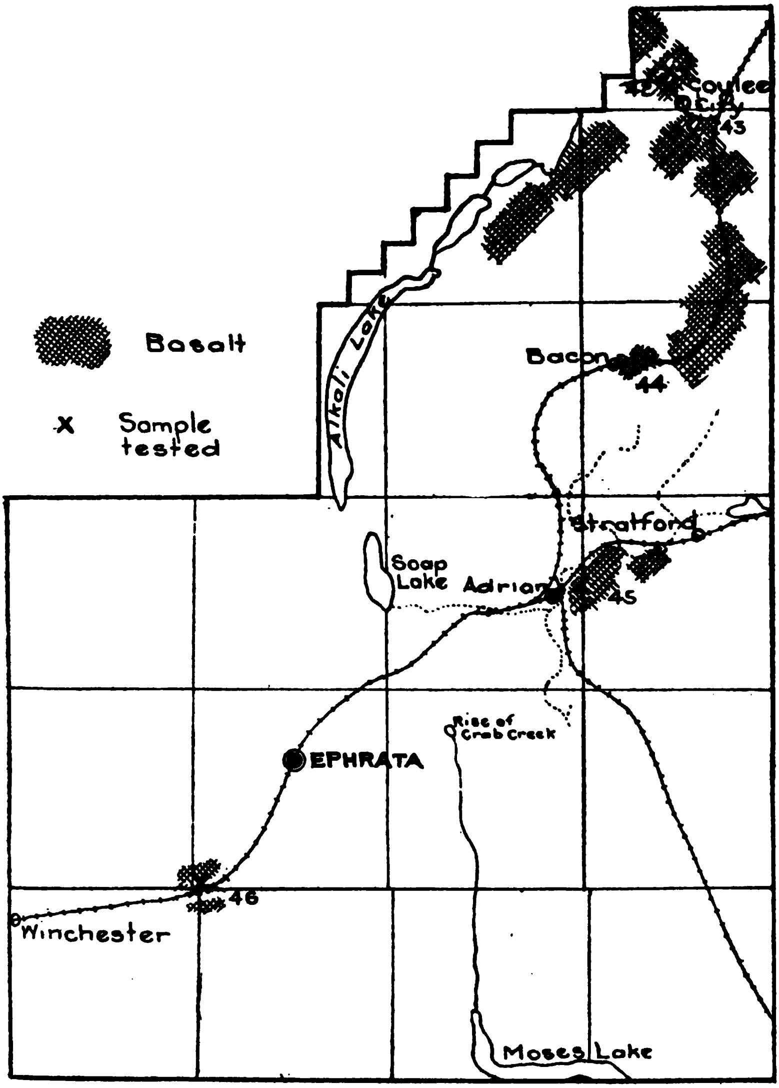
GRANT COUNTY.

GENERAL STATEMENT.

Grant county lies near the center of the great interior lava plateau of the state. It is a large county, having extreme dimensions of over 90 miles long by 50 miles wide. The northern panhandle of the county is a pronounced plateau, bordered on the western margin by Grand coulee. The southern rectangular portion of the county is a lower plateau, margined on the west by the canyon of the Columbia. On the extreme southern end of the county, running from west to east, are the prominent Saddle mountains. Frenchman hill is a low, broad ridge extending eastward from Columbia river to the valley of Lower Crab creek.

The annual rainfall of the county varies from 6 inches in the lowlands to 12 inches on the plateaus. Over the plateaus wheat may be grown but in the lowlands agriculture is not feasible without irrigation. At several localities irrigation projects are being developed and in time fruit raising and the growing of hay will doubtless be the chief industries. At the present time there is little demand for the best class of roads. Permanent highways will not come until the population of the county is much increased.

Very nearly all of the county has basalt as the bedrock. It outcrops as great cliffs along the walls of Grand coulee, at some places along Crab creek, and along the northern face of Saddle mountain. Some of the cuts along the Chicago, Milwaukee and Puget Sound Railway are in beds of sandstone and shale. Such deposits represent the sediments once laid down in an ancient lake which at one time occupied this locality. Satisfactory road materials may be sought in the better outcrops of basalt, and in the beds of gravel which border some of the stream courses.



EAST CENTRAL PART OF GRANT COUNTY.

Scale, 1 inch equals 6 miles.

ROAD MATERIALS TESTED.

Serial Number 42.

Coulee City is situated on the east brink of Grand coulee. From the town one can look up and down the coulee for many miles in both directions. The bottom of the coulee is several hundred feet below the town, and both of the coulee walls, as far distant as the eye can see, are made of huge basalt cliffs. The walls seem to be made of several distinct lava flows; the upper ones have weathered away or receded farther than the lower, leaving the cliffs terraced to a certain degree.

One and one-fourth miles northwest of Coulee City, and 100 feet south of the wagon road, is the north end of a bare basalt ridge which is several hundred feet long. At the point mentioned there is a little cliff about 25 feet high. The base of the cliff is about on a level with the town. The rock is fine grained and quite compact, the steam holes being very few and very small. It breaks with a shell-like fracture and sharp edges. When tested in the laboratory it proved to be a hard tough rock with high resistance to wear and low cementing value. It should make a satisfactory road material.

Serial Number 43.

Less than a mile south of Coulee City is the north wall of a small coulee which is a tributary of the larger Grand coulee. The floor of the tributary is about 200 feet lower than the level of the town. The small coulee exhibits a beautiful line of cliffs or palisades, with columnar jointing and long talus slopes. There are several distinct flows of lava, with abundant steam holes near the surface of each flow, and more compact rock below. A sample was collected from the upper ledge, 6 feet below the surface, on the north side of the coulee, about one-third mile south of the railway track. The test proved the rock to be a fine grained, gray-black, vitreous basalt. It is a hard, tough rock with high resistance to wear. It has good cementing value and in all respects is a first class road material.

In addition to the ledges above mentioned there are many more in the vicinity of Coulee City. In most of those examined steam holes are rather abundant. Along the railroad from Coulee Junction southward there are many cuts in basalt, varying in depth from 5 to 50 feet. Where the contact between two lava flows is exposed the top portion of the flow is seen to be usually full of steam holes while the base of the flow is denser rock. The texture of the rock varies from granular to compact. The toughness also varies, some of the rock being brittle and breaking with a shell-like fracture, while some of it is tough and hard to break. About one-half way between Coulee Junction and Bacon there is a cut 40 feet deep where the rock is compact and hard and breaks with a conchoidal fracture.

Serial Number 44.

This sample was taken at Bacon from a railway cut which is about 10 feet deep and 100 feet long. The laboratory examination demonstrated that the rock is fine grained, gray black, porous basalt. It is a hard rock, with average toughness, rather high resistance to wear and excellent cementing value. It should make excellent road material.

Serial Number 45.

At the junction of the Northern Pacific and Great Northern railways, 1 mile east of Adrian, and 50 feet south of the Great Northern track there is a basalt cliff from 25 to 50 feet long which parallels the track for 1,000 feet. Columnar jointing is conspicuous, and some of the individual columns are 3 feet in diameter and 30 feet high. The base of the cliff is above the level of the track. The texture of the rock varies from granular to compact. In the rock there are occasional small steam holes, some of them filled with spheres of a soft waxy looking mineral. There is but little soil upon the top of the cliff. A sample was taken from the broken rock at the foot of the cliff. A laboratory test proved that it was a porous, brownish gray, porphyritic rock. It is hard, possesses average toughness, rather high resistance to wear and fair cementing value. It should make a satisfactory road material.

Serial Number 46.

Between Ephrata and Winchester, about 3½ miles southwest of the former place, along the railway, there are some basalt ledges. About 500 feet south of the track the cliffs approximate 20 feet in height. Two ledges are exposed north of the track, a smaller one near at hand and a larger one about 500 feet away. The outcrops are several hundred feet long. The rock is weathered at the surface, but within it is fine grained to compact, hard and brittle, with few steam holes. A sample was taken from a ledge north of the railway. It proved to be a dense, very fine grained, gray black basalt, with high resistance to wear and good cementing value. It should make a very good road material.

Serial Number 47.

Beginning at a point one mile east of Crater, and extending for several miles west, large amounts of basalt are exposed along the railway. The rock varies much in character, the chief difference being in the relative abundance of steam holes. Every variety may be found from pumice to compact basalt. Much of the rock exhibits columnar jointing and that which does has fewer steam holes.

About 1 mile northwest of Crater there is a tunnel through the basalt. From the tunnel southeast for 2,000 feet the track is bounded on the north side by a perpendicular cliff 100 feet or more in height. A sample was taken from a cliff above the track at a point 1,000 feet southeast of the tunnel. The cliff has a sheer face of 100 feet, wherein the rock is hard, compact, dark colored, and almost wholly free from steam holes. When tested the rock showed a high resistance to wear and fair cementing value. It should make a satisfactory road material.

Along the line of the Chicago, Milwaukee and Puget Sound Railway, in the southern part of the county, there are frequent cliffs of rock, generally basalt, which rise to 300 feet or more above the track. The rock as a rule is very porous and unsuited for road material. The best rock is the black basalt near Smyrna where the cliffs range from 10 to 75 feet in height.

ISLAND COUNTY.

This county is made up wholly of islands, chiefly Whidbey and Camano, each being long and narrow. Transportation by water is so common that the necessity for a system of highways is less critical in this county than in others. The towns are practically all located on the water's edge. Agriculture makes slow progress because of the difficulties in the way of clearing the land. The soil is mostly very good and an agricultural community will be the rule at some time in the future.

The only rock outcrops are those at the extreme northern end of Whidbey island, on Deception Pass. The rock here is mostly sandstone and slate, occurring as cliffs of 300 feet or so, along the beach. No samples were taken of this rock because a state quarry has been established on the opposite side of Deception Pass, on Fidalgo island. (Described under Skagit county, Serial Number 103). Practically all of the surface of Island county is covered with glacial deposits. These are mostly till with occasional beds of sand and gravel. The till consists of pebbles cemented together with clay. When used in surfacing a highway which is properly graded and drained the till makes a good road bed, especially where the traffic is light. The gravel deposits are also suitable for ordinary roads and will prove satisfactory for all save the trunk lines. With the abundance of glacial deposits at hand it is not likely that this county will need much crushed rock for some years.

JEFFERSON COUNTY.

GENERAL STATEMENT.

Jefferson county extends from Puget Sound westward through the heart of the Olympic mountains to the Pacific ocean. Within the county there is every variety of surface from low plains to rugged mountains. The rainfall is sufficiently high to insure a forest growth everywhere, except on the rocky mountain slopes where there is no soil. A large percentage of the county is within the Olympic Forest Reserve. The lumber industry has been the principal one to this time, but as the land is cleared farming becomes more and more important. The towns are all located at the eastern end of the county. Very few settlers live west of the Olympics, and none within those mountains. The highways of the county are few in number and are all in the eastern part where they connect the towns with the country districts. A large part of the transportation is by water so that the demand for improved highways is not as keen as it is in the interior counties.

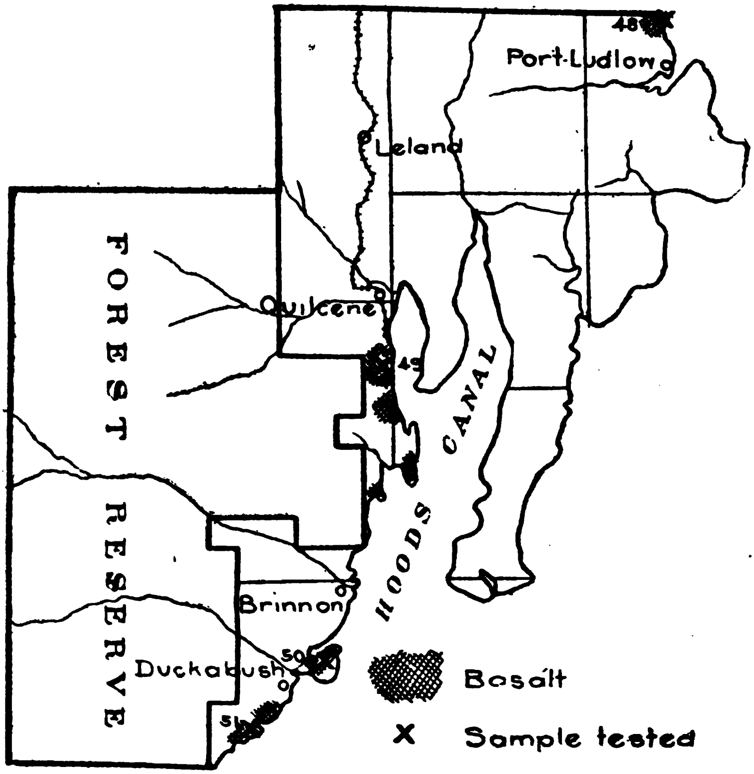


FIG. 20. Southeastern part of Jefferson county.
Scale, 1 inch equals 6 miles.

About all of the eastern end of the county is surfaced with glacial materials, mostly till and gravel. Both of these may be used to advantage where roads have been properly graded and where the traffic is not excessive. For some time such materials may probably be depended upon for the road building of this county. When the necessity arises for the use of crushed rock in surfacing roads good material may be had along the shores of Hood's canal, very convenient for shipment. At a number of places dikes of basalt occur where they have been pushed up from below, through the country rock of sandstones and shales. As a rule basalt of good quality may be found at points not far removed from where it may be needed.

ROAD MATERIALS TESTED.

Serial Number 48.

Between Port Ludlow and Chimacum, on Admiralty inlet, is what is known as Basalt Point. This point has a maximum height of 100 feet, with rather gentle slopes, broken at the water's edge by low cliffs of rock from 5 to 20 feet high. The soil is so thin that the rock is exposed at many places upon the hill. Similar rock also outcrops immediately north of Basalt Point, between there and Olele Point.

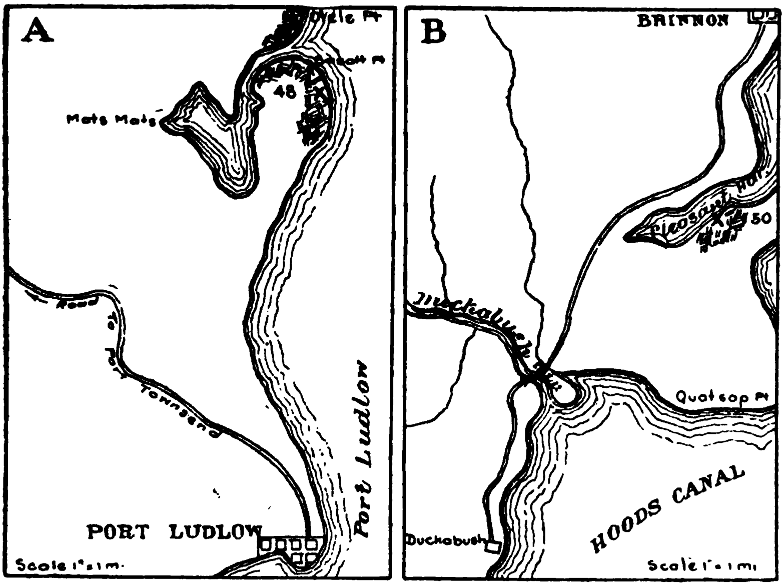


FIG. 21. A—Basalt outcrop north of Port Ludlow. B—Basalt ledges south of Brinnon.

The surface rock of Basalt Point is a soft, weathered, fine grained, brittle basalt. The steam holes which once existed in it have been filled with spherical masses of quartz, calcite, and other minerals. A sample was taken at the north end of the point, about 6 feet above the water. According to the laboratory test it is a dark gray, fine grained, highly altered basalt. It has average resistance to wear and fair cementing value. It should make a satisfactory road material.

Scows may be floated into Mats Mats bay at any stage of the tide, and a sheltered anchorage found. The present owner of Basalt Point and all the land about it is Mr. G. H. Clark, of Port Townsend.

Serial Number 49.

On the west side of Hood's canal, in this county, the topography is rather rugged since the Olympics approach so close to the water. The foothills in some cases slope very steeply to the canal, affording good rock exposures. On the west side of Quilcene bay, opposite the south end of Bolton penninsula, basalt outcrops for a distance of 2 miles. Precipitous cliffs of this rock drop down to the water, and in some cases with little or no beach at the foot. At many places quarry faces several hundred feet in height could easily be developed. The surface rock is rather soft and brittle, dark in color, and with the original steam cavities filled with spheres of quartz and other minerals. A sample of fresh or unweathered rock was taken from the foot of the cliff about 3 miles south of the town of Quilcene. When tested the basalt proved to be a hard, tough rock with average resistance to wear. It has excellent cementing value and should make a first-class road material.

About one-half mile north of Quilcene is a large gravel bank. South of Quilcene bay, along Pulali and Wawa points, low ledges of soft basalt are exposed, as well as at Brinnon. A good working face could not be obtained at any of these places, even if the rock were good, as the banks are too low.

Serial Number 50.

About 2½ miles south of Brinnon, and on the south side ot Pleasant harbor, there is a basalt cliff several hundred feet long which has a perpendicular face varying in height from 10 feet to 40 feet. Just inside the entrance to the harbor, on the south side, the cliff has a sheer face over 25 feet high, with columnar jointing well developed. The amount of overburden is small. The rock is fine grained and compact, and quite free from steam holes. A sample was taken from near the base of the cliff. The laboratory test proved the rock to have high resistance to wear and excellent cementing value. Taking all its qualities into account it should make an excellent road material.

Serial Number 51.

Along the shore from Duckabush south for 2 miles low basalt ledges outcrop. The slope of the shore is so gentle that it would be necessary to work back into the hill several hundred feet to secure a good quarry face. Much of the rock is soft, granular, and contains steam holes. About 2 miles south of Duckabush, on the south side of McDonald's cove, there is a basalt cliff from 10 to 25 feet high. There is a gentle slope above the cliff and a rather heavy overburden. Scows can reach the cliff only at high tide. Some columnar jointing appears in the cliff, and steam cavities are absent. A sample was collected from the foot of the ledge at the mouth of the cove. According to the test the rock is a fine grained basalt, soft, with average wearing value, low toughness and excellent cementing value. It should make a very good road material for light traffic.

KING COUNTY.

GENERAL STATEMENT.

King county extends from the shores of Puget Sound eastward to the summit line of the Cascade mountains. Along the western border of the county the country is low, with rather uniform uplands between the wide valley bottoms. East of the belt of lowlands are the foothills of the Cascades. The eastern half of the county is very mountainous, the contrasts between the high divides and the deep valleys being very strong.

Over the lowlands of the western part of the county there is a thick mantle of glacial drift, with very few rock outcrops.

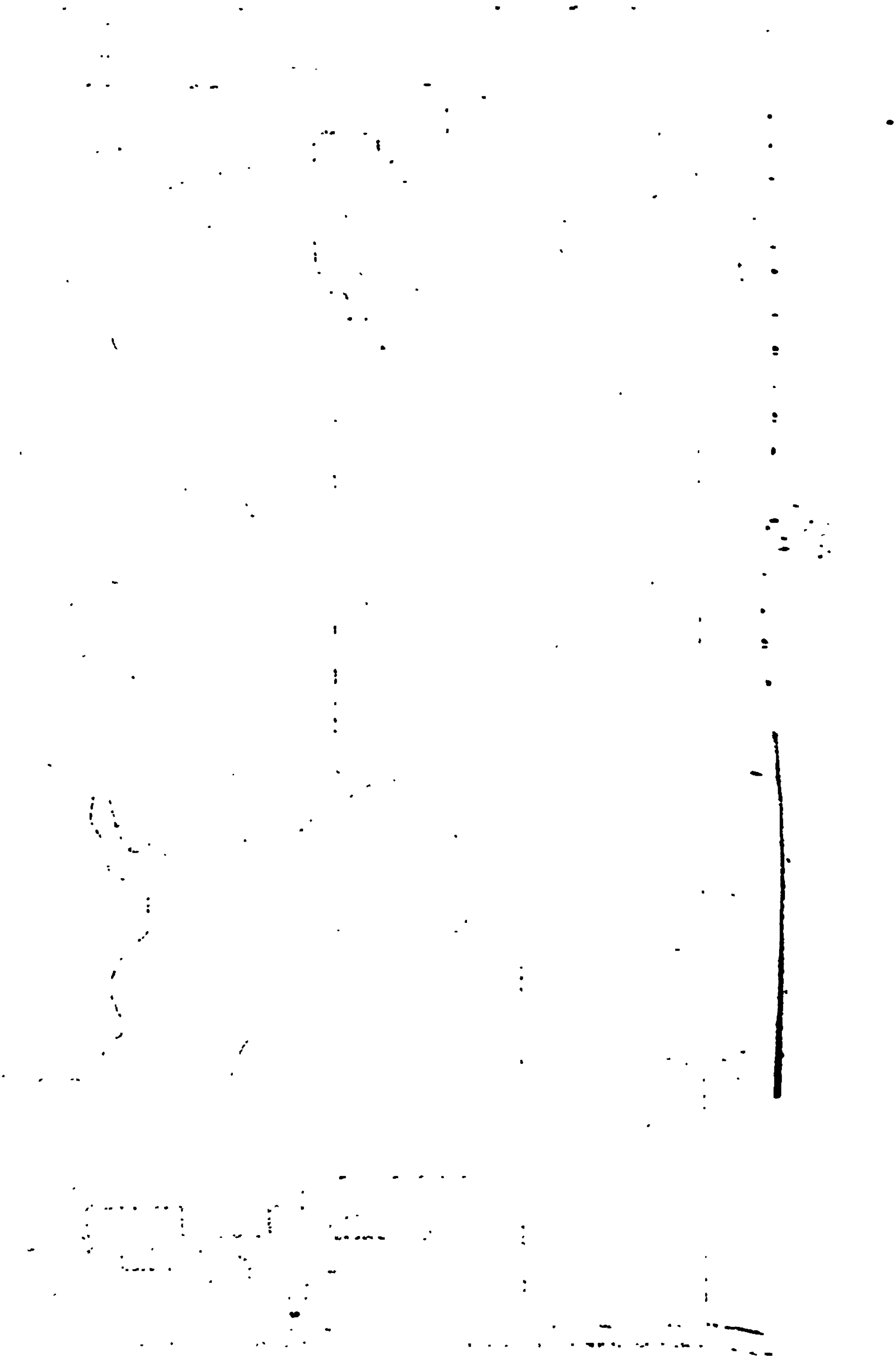
The latter become more numerous as one goes eastward un higher mountains are reached where ledges of rock occur where. The glacial material is made up chiefly of till, beds of gravel, sand and clay. Till and gravel have both very generally used in road building where the traffic has light. When the roadway is well prepared by draining grading such materials make a satisfactory road. Fo trunk lines or main highways crushed rock is now being erally used. Several varieties of rock are available for u this county, chiefly andesite, basalt, and granite or gran rite. Fortunately outcrops of good rock occur rather quently so that no very long hauls will be necessary in bui the roads of the county. Besides the rocks within the co other deposits may be drawn upon for road building the ledges outcrop about the shores of the sound convenien shipment.

The people of the county nearly all live on the lowlands tide-water. Macadamized roads are now building connecting centers of population. Two lines of first-class highways being constructed from Seattle north, and one line south. east and west line, from Seattle through Snoqualmie valle Snoqualmie Pass, is being constructed in sections. A syste macadamized highways will soon serve the more thickly p lated parts of the county.

ROAD MATERIALS TESTED.

Serial Number 52.

Near Duwamish Station, on the line of the Puget So Electric Railway, a basalt quarry has been in operation some years. The quarry is now owned by the Bell-Scott C pany, with offices in Seattle. The quarry is on the east side a basalt hill, adjacent to the electric line, by which the rock shipped. A quarry face 300 feet long and 100 feet high been developed. There is on an average 2 or 3 feet of soil cov ing, with a few feet of broken, weathered rock, and the remaind columnar or jointed blue-black basalt. Steam holes are ve rare and the porosity slight. The rock breaks with a she



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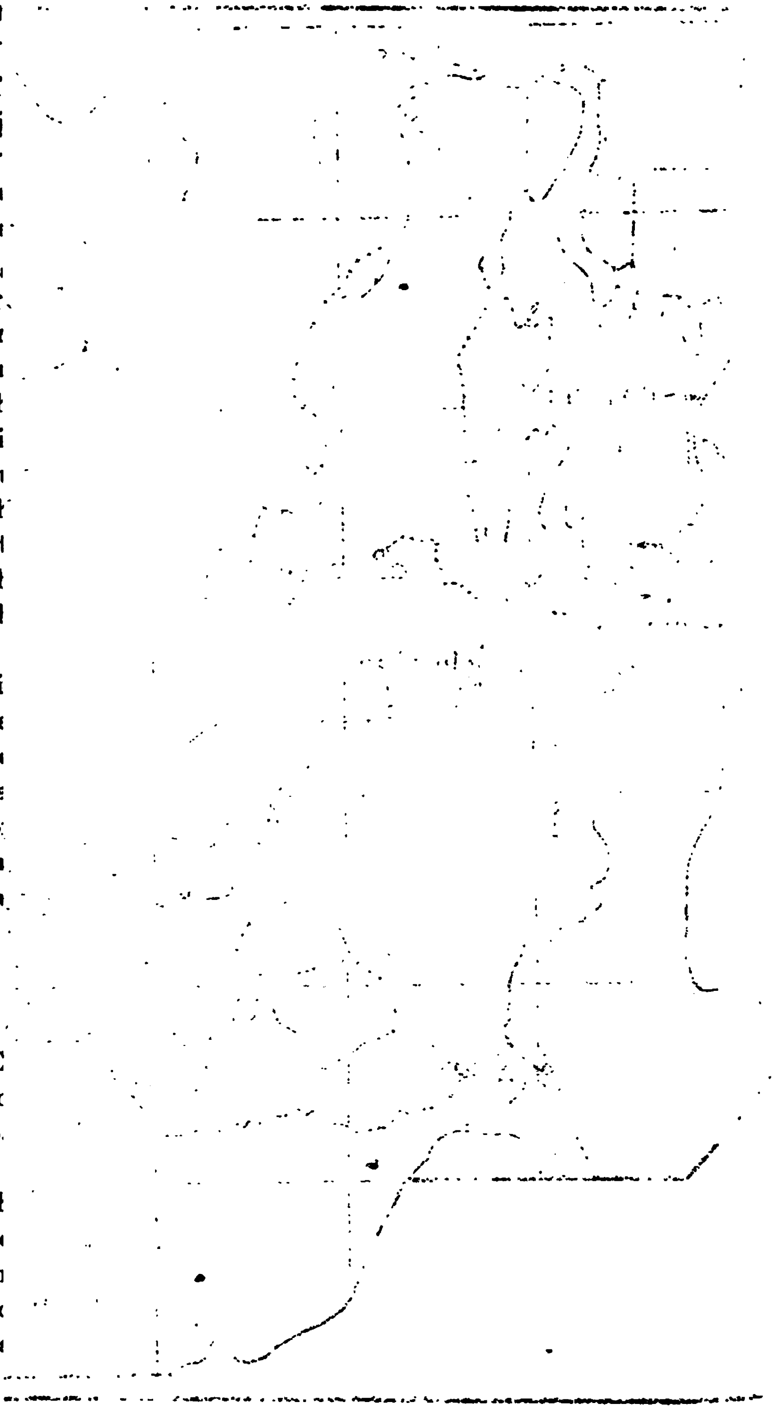


like fracture and sharp edges. A test made of a sample taken from the more massive rock showed it to be a medium grained, dark gray basalt, with average hardness and high resistance to wear. It is a tough rock and when rightly used in highway construction should make an excellent road material.

At the quarry, in the crushing plant, a Number 2 and Number 5 Gates crusher (Class D), are used, with a capacity of from 20 to 45 tons per hour. Twenty men are ordinarily employed. The rock is dropped from the quarry floor to the crushers, and then lifted in conveyors to the screens and bins. The crushed rock has been used extensively on the roads of the county, and on the streets and boulevards of Seattle. It is also used in concrete work as well as in asphalting.

Serial Number 53.

On the hillside immediately west of the foot of Lake Washington, near Earlington, there are a few outcrops of andesite. As a rule the outcrops are hidden among the underbrush of the forest and are difficult to find. At a few places, near together, the overburden has been stripped away and several tons of the rock have been blasted out to determine the quality of the stone. The surface rock is too soft to be of practical use in road build-

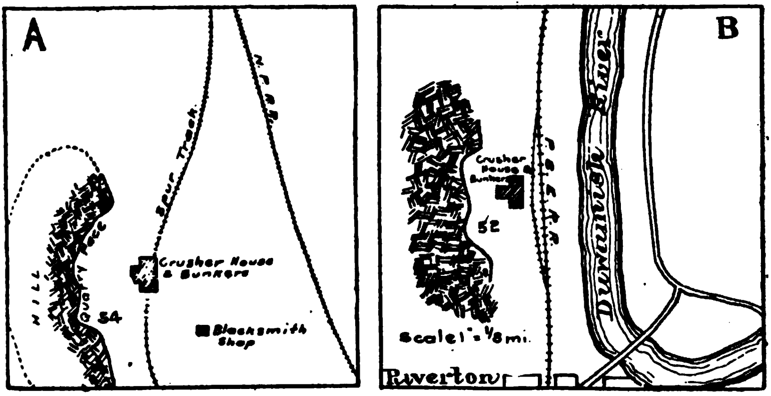


FIG. 22. A—County quarry one mile south of Snoqualmie. B—Basalt quarry and crushing plant between Riverton and Duwamish.

ing. It is possible that the deeper rock might be hard enough to use in this connection. It is located adjacent to the city of Seattle and would be very valuable in street work if it possesses the proper qualities. A sample was taken from the hardest rock that could be found where a small test pit was opened on land belonging to Mr. Watson Allen. The test proved the rock to be a light gray, highly decomposed andesite; a rather soft rock, a little low in toughness, with average resistance to wear, and excellent cementing value. It should make a fairly satisfactory road material.

Serial Number 54.

About 1½ miles southeast of Snoqualmie is a quarry which is the property of King county. The quarry is opened in the side of a hill which is about 400 feet long in a north and south direction, and about half as wide. The hill rises to a maximum height of 80 feet above the surrounding plain. The hill is entirely isolated, and is a remnant of erosion in the broad valley of Snoqualmie river. A spur track about 800 feet long connects the quarry with the Northern Pacific Railway, over which the crushed rock is shipped.

There is a mixture of several varieties of rock in the hill. The bulk of the mass is andesite, with dikes of other igneous rocks as well as some slate. A sample was taken from the andesite as representing the best road material in the hill. According to the laboratory test it is a highly altered andesite, hard and tough, with high resistance to wear and fair cementing value. It should make a satisfactory road material. The andesite should be separated from the other rocks in quarrying and it alone used.

The county has purchased 27 acres of land and installed a plant with a gyratory crusher which has a capacity of 20 tons of rock per hour. After crushing, the rock is lifted in conveyors to the screens, from which it drops into the bins which have a capacity of 300 tons. The machinery is run by a 35 horse power steam engine.

Serial Number 55.

On the Great Northern Railway, near the King-Snohomish county line, at Halford Station, there are 2 granite quarries. One of these belongs to the Halford Granite Company and the other to the Great Northern Railway Company. The former company deals in cut and rough stone, building stone, street curbing and paving blocks. The railway company uses its rock in the construction of a sea wall between Seattle and Everett.

The quarry of the railway company has a face 600 feet long and approximately 250 feet high. The overburden is not great. The middle portion of the quarry is much jointed and rather more weathered than other parts. In other places the rock is more massive and therefore fresher and harder. The hardest rock is at the eastern end of the quarry and here a sample was taken. The rock is technically a granodiorite, although it is always known as a granite. It is light gray and coarse grained. According to the test it is a hard rock, with low toughness, average resistance to wear, and fair cementing value. It is only suitable for the foundation course in plain macadam construction.

Serial Number 56.

This sample was taken from a point one-fourth of a mile north of Scenic, alongside the railway track. At this place there is a steep rocky slope of 500 feet between the track above and the track below, where the railway makes a great loop in climbing the mountains. At the base of the slope a face of rock 40 feet high is exposed. At the foot of this cliff a sample was collected. The laboratory test proved it to be a coarse grained granodiorite; a hard rock with low toughness and fair cementing value. It is not recommended as a road material except in the foundation course.

Serial Number 57.

For some distance west of Hot Springs, along the Northern Pacific Railway, there are outcrops of rock which project as spurs from the mountain on the south. About one mile west of Hot Springs there is a rounded cliff with a steep face having a maximum height of 100 feet. Except for a little broken rock there is little or no overburden. A sample was taken near the east end of the cliff, from a ledge about 20 feet above the track.

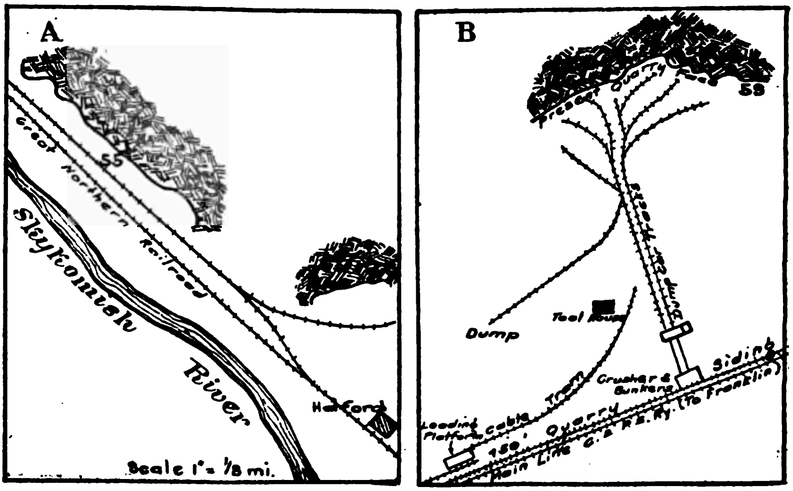


FIG. 23. A—Granite quarry at Halford. B—Quarry of Seattle Park Board near Franklin.

As proven by the test the rock is a dense, gray black, porphyritic basalt. It is a hard, tough rock, with high resistance to wear and low cementing value. It should make a satisfactory road material under heavy traffic.

Serial Number 58.

About one mile south of Veazie the Northern Pacific Railway operates a small quarry for the purpose of securing stone for ballast, rip-rap, etc. The quarry is on the side of a hill about 75 feet high and 300 feet long. A sample was taken at the south end of the quarry where the rock occurs in large columns. There is no overburden, and since the rock is in columnar form the quarry operations are very economical. The laboratory test showed the rock to be a medium grained, brownish gray diabase. It possesses average hardness and resistance to wear, rather low toughness and very high cementing value. It should make an excellent road material.

Two miles north of Enumclaw, near Birch schoolhouse, a precipitous face of basalt occurs, 300 feet long and 150 feet high. It is of a coarse grained and brittle character and is not believed to be desirable for use as a road material.

Serial Number 59.

This sample was taken from a quarry owned by the Seattle Park Board, and located about a half mile west of Franklin, alongside the track of the Columbia and Puget Sound Railway. The quarry is in a dike of basalt about 110 feet wide which lays between some sedimentary formations belonging to the coal measures of that region. The sedimentary strata, with included dike, have a north and south strike, and a westward dip of 75 degrees.

The sedimentary rocks which belong above the dike form an overburden on the basalt which becomes increasingly thicker and more difficult to remove as the quarry face is pushed further and further into the hill. A laboratory examination of the rock proved it to be an altered basalt. It is characterized by medium hardness and resistance to wear, with low toughness and excellent cementing value. It is a satisfactory material for macadam work.

Serial Number 60.

This sample was collected from a hill along the railway about 2 miles east of Hobart. The hill is about 250 feet in height above the railway grade, and distant from it about 300 yards. It is soil covered to about half its height, but the upper half of the hill is a rounded, bare boss of rock. A sample was tested out in the laboratory and proved to be a dense, fine grained, light greenish gray, highly altered andesite. It is a hard, tough rock with average resistance to wear and low cementing value. It should make a satisfactory road material under heavy traffic.

KITSAP COUNTY.

GENERAL STATEMENT.

Kitsap county is essentially a peninsula, situated between Hood's canal on the west and the main body of Puget Sound on the east. Its shores are greatly indented, abounding in good harbors, so that much of the transportation of the county is carried on by water. It is located within the Puget Sound lowland, so that no part of its gently rolling surface exceeds 600 feet above the sea. It was once heavily forested but the virgin timber is now largely removed. Because of its proximity

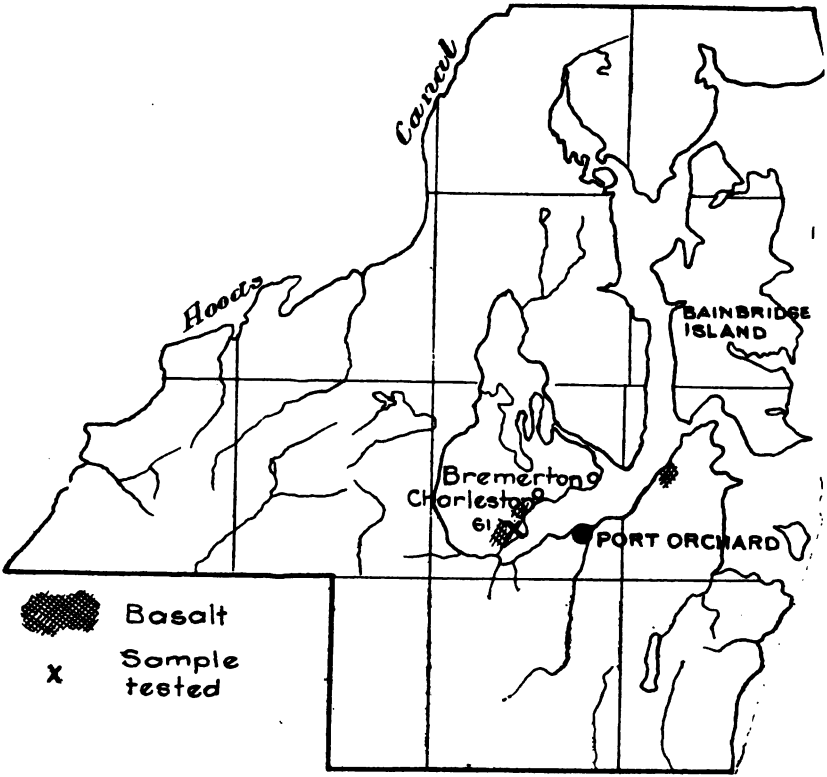


FIG. 24. Central part of Kitsap county.
Scale, 1 inch equals 6 miles.

to good markets the logged-off lands are being cleared for farms. The farms are generally small so that in certain localities the rural population has grown to the point where good roads are now necessary. As a rule the roads are short, extending from the interior of the peninsula to the nearest good harbor where there are wharves.

The major part of the county is deeply buried under a thick mantle of glacial sediments. The highways so far have been entirely made of these materials. The glacial till, composed of pebbles with a cement of clay, makes a fair road wherever the drainage and the grades are good. It is likely to be very dusty in summer and muddy in winter. Beds of gravel are generally distributed, as a part of the glacial deposits, and may be used in surfacing the highways. Bedrock appears at the surface but rarely and then usually about the shores of the Sound or along Hood's canal. It is prevailingly sedimentary in character, usually alternating layers of sandstone and shale. It is worthless as a source of road materials. Basalt is very scarce and the locality described below is the only well known accessible one. Igneous dikes occur in the low hills west of Chico but not in a convenient location for use in road building.

ROAD MATERIALS TESTED.

Serial Number 61.

On the northwest side of Sinclair inlet diabase is exposed along the beach for over a mile and a half. The highest ledges occur at the quarry of the Independent Asphalt Paving Company, with offices in Seattle. This quarry is situated 2½ miles southwest of Charleston, in the N. ½ of Sec. 33, T. 24 N., R. 1 E. The total length of the quarry is 2,000 feet, with an average height of 75 feet. Much of the quarry face is hidden by the broken rock which has been blasted off from above, making a talus slope at the base. There is less than a foot of soil on the rock at the top of the exposure. The hill rises gently from the rim of the quarry north to the county road, about 1,000 feet away. The base of the quarry is 150 feet from the beach.

The rock is a medium grained, black diabase, soft on the weathered surfaces but harder within. The formation throughout the quarry is jointed and broken. At the northeast end of the quarry there are some almost perfect hexagonal columns. Steam holes occur, generally small, but occasionally they are found with diameters of one-half inch or more. Many of them have become filled with calcite and other minerals. A sample of the best rock was selected for a laboratory test. It proved to be a hard rock with average toughness and resistance to wear and very good cementing value. It should make a first-class road material.

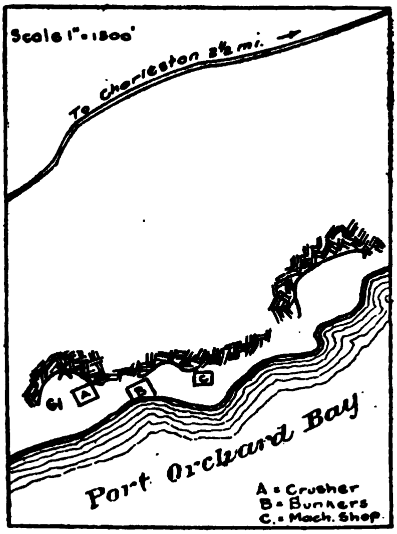


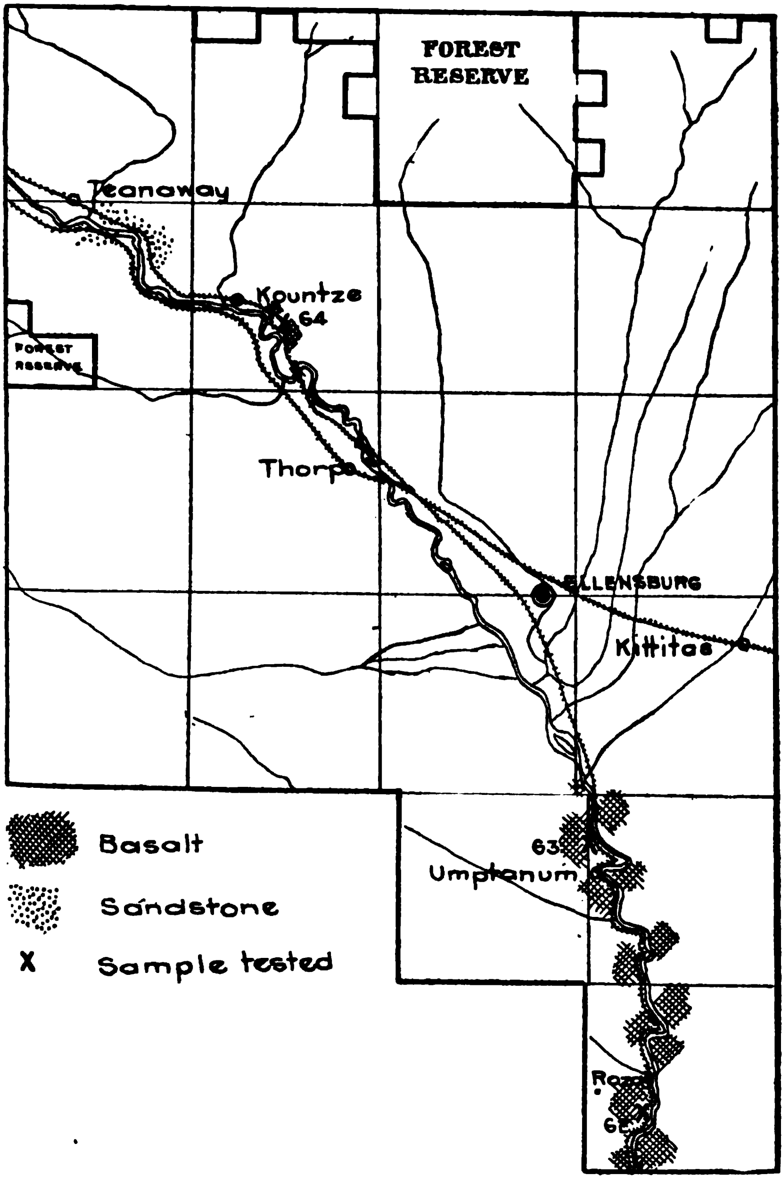
FIG. 25. Quarry 2½ miles southwest of Charleston.

The rock is crushed after quarrying and then scowed to Seattle and Tacoma where it is used in asphalting, in macadamizing, and for concrete making. The crusher has a capacity of 200 yards per 10 hours for coarse rock, and 150 yards for finer rock.

KITTITAS COUNTY.

GENERAL STATEMENT.

This county extends from the summit of the Cascade mountains eastward to Columbia river. The general topography of the western half of the county is that of a rugged mountainous region; that of the eastern half a broken plateau. The Columbia has incised a deep canyon along the eastern margin of the county. Yakima river has eroded a valley of unusual width, except in its upper portion within the mountains, and in the southern part of the county, below Thrall, where it has



PART OF KITTITAS COUNTY, NEAR ELLENSBURG.

Scale, 1 inch equals 6 miles.

formed a remarkable canyon. The widest part of the valley is in the vicinity of Ellensburg, where it is locally known as the Kittitas valley.

The majority of the people of the county live within Kittitas valley where irrigation has led to the development of many fine hay and fruit ranches. The principal towns of the upper Yakima valley, Cle Elum and Roslyn, are located in a prominent coal mining district. In the thickly settled portions of the county there is now a necessity for good roads. So much traffic has developed that the trunk roads at least should be macadamized. A first-class highway is needed which will run lengthwise of Yakima valley, feeders or branch roads extending from it to the ranches along the borders of the valley.

The best road material in the county is basalt. This rock occurs in unlimited quantities along the canyon walls south of Thrall. At many points it outcrops along the Northern Pacific railway between Ellensburg and Easton. It occurs in the cuts along the Chicago, Milwaukee and Puget Sound railway between Ellensburg and Columbia river, and between Ellensburg and Snoqualmie pass. It is so widespread in its occurrence that it will not need to be transported very far in any road building within the county.

Along Yakima river at several places benches of gravel occur. The gravel is usually of good quality and is of value in surfacing the roads which have a light travel. Between Ellensburg and Thorp gravel deposits are rather frequent. Immediately northwest of Thorp, on the Chicago, Milwaukee and Puget Sound railway, gravel is exposed in a large bank at least 40 feet high and several hundred feet long.

ROAD MATERIALS TESTED.

Serial Number 62.

Cliffs of basalt, hundreds of feet in height, make up the walls of the Yakima canyon. In most of the higher cliffs several distinct flows of lava may be seen, the contacts usually being quite noticeable. Columnar jointing is very common. As a rule the rock contains steam holes in abundance, although the amount varies. There is much compact, hard rock, but where it is overlaid by flows of porous, soft rock, it can not be quarried economically.

This sample was taken about one-third of a mile south of Roza, near the south end of the first cliff, from the base of the ledge. This cliff is about 250 feet long and all told at least 100 feet high. The hill behind it rises to a height of several hundred feet by a series of steps. The rock in the cliff at the base shows columnar jointing. It is rather hard and has a fresh, unaltered appearance on a fractured surface. It is a fine-grained rock, breaks in a shell-like fashion, and has only a very few steam holes. The rock of the south half of the cliff, where the sample was taken, appears to be somewhat harder than that of the north part. According to the laboratory test it is a tough rock with high resistance to wear and low cementing value. It should make a satisfactory road material under very heavy traffic.

Serial Number 63.

About 2 miles north of Umptanum, as the river and the railway wind, there is an abandoned quarry on the west canyon wall. The face of rock in the quarry is 225 feet long and from 30 to 40 feet in height. It has an overburden varying from 1 to 4 feet. There is approximately a 35-degree slope on the canyon side above the quarry. The rock is very uniform in appearance and free from steam holes. It is jointed in great, heavy columns, often 4 feet in diameter, extending from the base to the top of the quarry. The rock itself is a dark gray, heavy, fine grained basalt, and fairly hard, although scratched with soft steel. It is very fresh looking and has not suffered any alteration. A sample was collected from the rock within the quarry. According to the test made upon it it is a tough rock with high resistance to wear and low cementing value. It should make a satisfactory road material for heavy traffic.

The floor of this quarry is not over 4 feet above the track of the Northern Pacific railway, which is 125 feet distant. The quarry is connected with the railway by a spur track. By going up the slope above the quarry and stripping off the soil and broken rock a rock face of almost any size could be developed.

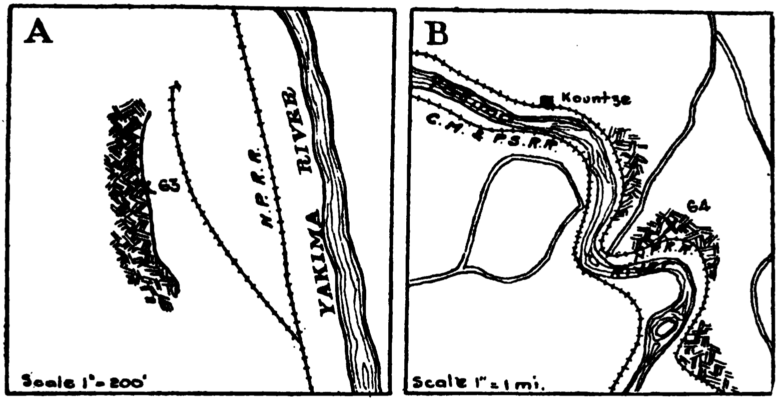


FIG. 26. A—Basalt quarry near Umptanum. B—Basalt cliffs near Kountze.

Serial Number 64.

About 4 miles northwest of Thorp, in Sec. 28, T. 19 N., R. 17 E., there is a basalt cliff along the north side of the Northern Pacific railway track. It is several hundred feet long and for most of the way is more than 100 feet high. Back of the first cliff there is a second one from 75 to 100 feet in height. There is much columnar jointing in the upper cliff but less in the lower. The topmost portion of the lower flow has quite abundant steam holes and a few also appear in the upper flow. In general the rock consists of fine-grained, gray basalt, of varying hardness. A sample was collected from the base of a cliff about 70 feet above the track. When tested it demonstrated itself to be a hard, tough rock with high resistance to wear and low cementing value. Under heavy traffic this material could be used in a satisfactory way.

A half mile east of Kountze there is a cliff averaging 100 feet in height, several hundred feet long, on the north side of the Northern Pacific railway. It is made up of a fine-grained, tough, hard basalt, containing very few steam holes. Although it was not tested the rock can be safely recommended as a road material.

Serial Number 65.

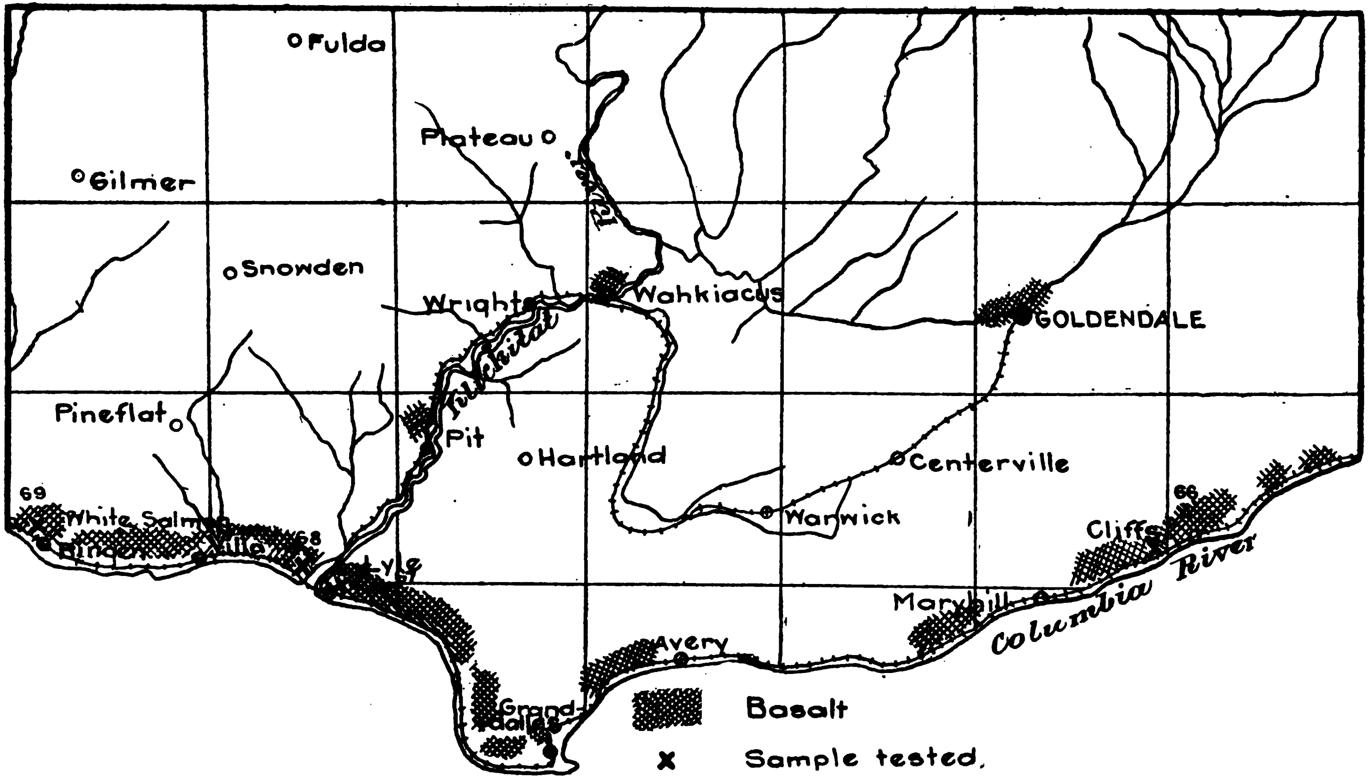
Immediately west of Easton there is a rock cliff with a perpendicular face about 50 feet in height. The cliff has been tunneled by the Chicago, Milwaukee and Puget Sound railway, and the broken rock from the tunnel and neighboring cuts makes a great slope which extends to the track of the Northern Pacific railway, farther down the mountain side. The fresh rock is white in color but is pinkish where altered. The rock softens under the weather, and becomes porous. There is but little overburden on the ledge. A sample was collected from the rock taken out in driving the tunnel. According to the laboratory test the rock is a medium grained, yellowish gray syenite. It offers very high resistance to wear and has fair cementing value. It is best suited for roads subjected to heavy traffic.

KLICKITAT COUNTY.

GENERAL STATEMENT.

Klickitat county is located on the southern boundary of the state and it has a frontage along Columbia river of about 90 miles. Its general topography is that of a plateau, gently sloping from north to south. The western end of the county extends well into the Cascade mountains; the eastern end is a part of the great interior plain of the state. In the western half of the county the streams flow in deep valleys, usually canyon-like in character; in the eastern half the county is rolling and the valleys less pronounced.

Agriculture is the principal industry of the county. Irrigation is necessary in all the lowlands, but on the higher portions of the plateau the natural rainfall is sufficient for wheat raising. Irrigated ranches are coming to be numerous on the benches along Columbia river, and in the valleys of the western part of the county where water may be had readily. The irrigated valleys will soon maintain a large population and a



Scale, 1 inch equals 6 miles.

CENTRAL PART OF KLICKITAT COUNTY.

system of good roads will be imperative. Thus far but little attention has been given to the matter of first-class highways. As noted below there is an abundance of good road material at hand whenever the time comes for the construction of macadamized roads.

As far as known the country rock is all basalt. It outcrops abundantly almost everywhere except over certain localities in the eastern part of the county where there is a thick mantle of soil. It occurs as great cliffs along Columbia river, almost all of the way from the western margin of the county to the eastern end. It is especially prominent along the lower Klickitat valley for many miles. Along all the streams in the western end of the county it outcrops in great cliffs. In many instances the rock contains such an abundance of cavities that it would be valueless in surfacing a road. Very frequently the rock occurs in great columnar masses and as a rule excellent material for macadamizing may be had when this is true. There is probably no county in the state that has such an abundance of good road material as Klickitat county.

ROAD MATERIALS TESTED.

Serial Number 66.

This sample was taken at the base of a 200-foot cliff along the railway one and one-fourth miles west of Cliffs. The cliff extends unbroken along the track for at least 1,600 feet. The rock is massive in character, hard and tough, and free from steam holes. According to the laboratory test it is a medium-grained, greenish black basalt, with a rather high resistance to wear and fair cementing value. It should be regarded as a satisfactory road material.

Excellent quarry sites in good basalt rock occur in the hills back of Cliffs and about 200 yards from the railway. Along the railway from Cliffs eastward basalt of good quality is found at several places. Workable faces of good rock occur at a locality three miles east of Cliffs, and also at Fountain and Sandal.

Between Maryhill and Cliffs high walls of rock border the railway for about one-half the distance. The rock is generally of a brownish color, coarse-grained, and more or less porous by reason of included steam holes. As Cliffs is approached the quality of the rock improves very markedly as it becomes darker in color, finer grained, much tougher, and more free from cavities.

Serial Number 67.

This sample was taken at the west end of tunnel No. 11, one-half east of Lyle. The rock is a hard, black columnar basalt, containing a few small steam holes. Rock of this character and quality is abundant for a distance of 500 yards eastward from the tunnel. The cliff in several places has a height of from 150 feet to 200 feet. The report of the test shows that the rock has average resistance to wear, rather low toughness, and good cementing value. It should make a good road material. This is probably the best quarry site in the county on account of the height of the cliff, proximity to rail and water transportation, and situation as regards the principal towns of the region.

Serial Number 68.

There is a low cliff of basalt one mile west of Lyle, near the bridge across Klickitat river. The rock is peculiar in that it splits into plates of moderate thickness with approximately plane surfaces. In some places the rock is indistinctly columnar, and everywhere is quite free from steam holes. The sample taken here was proven in the laboratory test to be a rather hard rock with average toughness and good cementing value. If used in highway construction it should make a satisfactory road material.

Numerous cliffs of good basalt rock occur along the railway track between Lyle and Bingen. The cliffs often reach heights of 200 feet and are generally accompanied by heavy slopes of broken rock. The rock is often in the form of vertical columns and is jointed to such a degree that it is easily quarried. Localities may be found where the rock is dense and hard and very free from steam holes.

Serial Number 69.

One mile west of Bingen the railway track was cut through columnar basalt for 450 feet. The cut varies from 30 to 40 feet in depth. The columns, usually from 10 to 12 inches in diameter, stand in a vertical position, and are strikingly regular. The rock is covered by a thin layer of soil; otherwise there is no overburden and the rock is unweathered. The sample collected here was identified in the laboratory test as a dense, fine-grained, gray-black basalt; a hard and very tough rock with high resistance to wear and fair cementing value. It should make a satisfactory road material.

East of Bingen rock similar to the above occurs in high cliffs. It is usually in large columns and contains some steam holes. Two miles east of Bingen there is such a cliff 70 feet high and several hundred feet long. Rock of excellent quality occurs near Vila, where the average height of the exposed face is about 40 feet.

Along the railway from Lyle to Goldendale basalt occurs conspicuously in the walls of the Klickitat canyon for 15 miles northward from Lyle. Beyond this rock is only occasionally exposed, as for instance in the case of the scabrock on the low hills near Goldendale. The rock in Klickitat canyon is basalt of fairly good quality, dark in color, compact, and usually columnar. The cliffs are low and heavily covered above with soil. The best rock occurs in a cliff 1 mile from Pitt, or 11 miles from Lyle. A similar cliff occurs between Wahkiacus and Warrick.

LEWIS COUNTY.

GENERAL STATEMENT.

Lewis county extends from the summit of the Cascades westward for over 90 miles. The eastern half of the county lies within the foothills and higher ridges of the Cascades; the extreme western end extends into the low mountains of the Coast range; between these two highlands there is a broad north and south valley which is in reality an extension southward of the Puget Sound basin.

The annual rainfall of the county varies with the topography and the distance from the sea. In the lowlands it averages 50 inches per year; in the highlands, chiefly along the western border, it averages 70 inches per year. Because of the large rainfall a heavy forest growth, equal to that found anywhere in the state, once covered nearly every portion of the county. In the lowlands a large part of the forest has been removed, and much of the cut-over land has been cleared for farms. This is particularly true in the broad valleys of Cowlitz and Chehalis rivers, and their tributary valleys, where the soil is excellent and agricultural conditions are highly favorable. Important farming communities have developed at many places and good roads connecting these with each other and with the

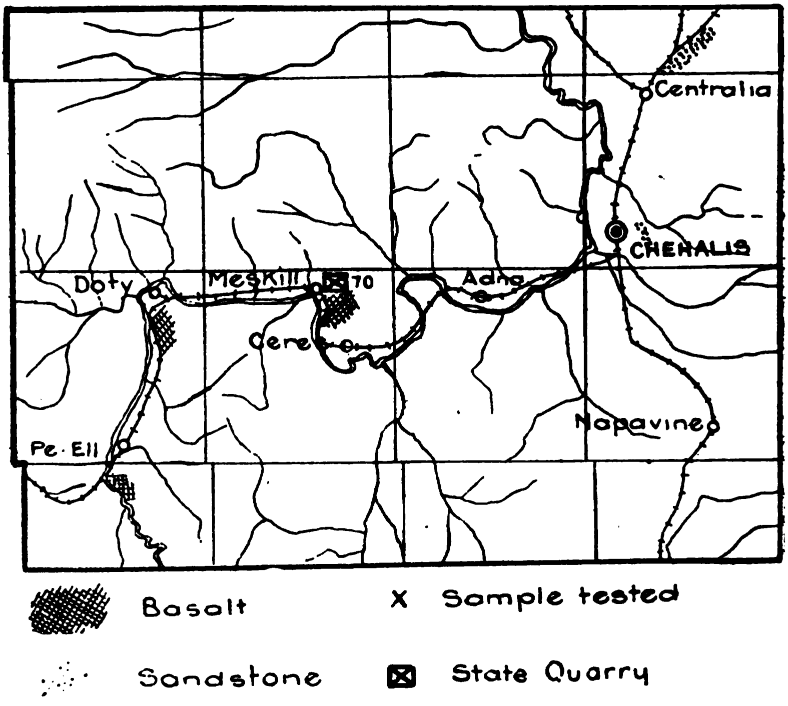


FIG. 27. Northwestern portion of Lewis county.
Scale, 1 inch equals 6 miles.

towns have been building for some years. This has been one of the leading counties in the state in the matter of good roads. Trunk highways have been properly laid out and some of them surfaced with crushed rock or gravel.

The rocks which outcrop in the settled parts of the county are of two classes, viz. sedimentary formations, such as sandstones and shales, and dikes of basalt. The former is of no value in road building; the latter is a valuable material for macadamizing and the county is fortunate in having several good deposits of it. Besides the bed-rock which may be used in road work, banks of gravel occur very frequently. In some instances they extend over broad areas in the form of plains, and at other times form benches or bars along the streams. Gravel has been used satisfactorily on many roads where the amount of travel is not large.

ROAD MATERIALS TESTED.

Serial Number 70.

At Meskill, 13 miles west of Chehalis, on the South Bend branch of the Northern Pacific railway, a basalt quarry has been operated for some years. At this locality there is a long hill paralleling the track for several thousand feet and at the Meskill end of the hill a quarry has been opened. In the quarry there is a face of basalt exposed approximately 150 feet long and 40 feet high. An average of about 3 feet of soil and weathered rock is stripped off the top and thrown away. The basalt is very hard, except at the extreme north end of the quarry. There is some columnar jointing in the middle portion of the quarry. A sample was taken from near the south end of the quarry. According to the test made upon it, it is a fine-grained, dark gray basalt of average hardness and toughness. It offers rather high resistance to wear and has fair cementing value. The results of the test show that it should make a satfactory road material.

This quarry was first opened and operated by the county but is now owned and controlled by the state. It is operated by convicts who are housed in a stockade adjoining. In the quarry rock is first thrown into steel cars and then pushed over a horizontal track for about 200 feet and dropped into a gyratory crusher. After crushing it is conveyed upward into the screens and bins. The bins have a capacity of 200 cubic yards.

A few hundred feet south of the quarry described, on land belonging to the state, the basalt hill becomes much steeper and higher. At this point the rock rises as a bold bluff from the east side of the railway track, the face of the hill having an inclination of about 45 degrees. At the highest point of the hill a height of 185 feet above the track is reached. The face of the bluff is practically barren of soil, so that the amount of stripping required would be small. On the face of the hill, where it is highest, there is a good opportunity to open a quarry in basalt and install a crushing plant, using a gravity system wholly. The rock at this place is very hard and tough, fine-grained, compact and unusually free from steam holes and other cavities. It breaks with a shell-like fracture and sharp edges, and appears to be fresh and unweathered.

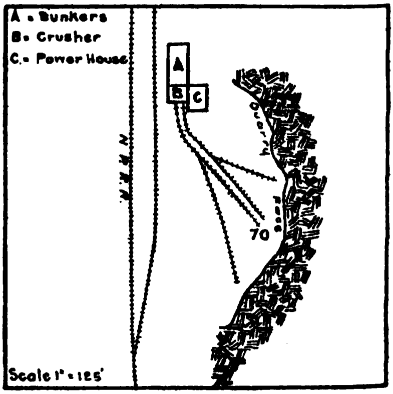


FIG. 28. State quarry and crushing plant at Meskill.

About one-half mile south of Doty, on the east side of the railway, there is a cliff of basalt several hundred feet long and about 30 feet high. The foot of the cliff is approximately 500 feet east of the track, and there is a slope of broken rock about 200 feet wide, extending from the base of the cliff toward the railway. The vertical distance from the foot of the slide rock to the top of the cliff is about 75 feet. Farther to the southwest the hill increases in height, but this would be a greater distance from the railroad. There is but little overburden to be seen on the brow of the hill. A small fill and a short spur track would connect this rock deposit with the main line. A sample of rock was collected here for a test but it was lost in shipment. The rock nearest the track is a dark, heavy, compact, rather hard basalt, free from steam holes.

South of Pe Ell, above the bridge where the railway crosses Chehalis river, the stream has cut a small gorge in a ledge of basalt. On the surface the rock is too weathered and soft to have any value. About 2 miles west of Chehalis, and a mile south of Littell, there are some small outcrops of basalt where a little rock has been taken out for road work. Since the opening of the quarry at Meskill these workings have been abandoned.

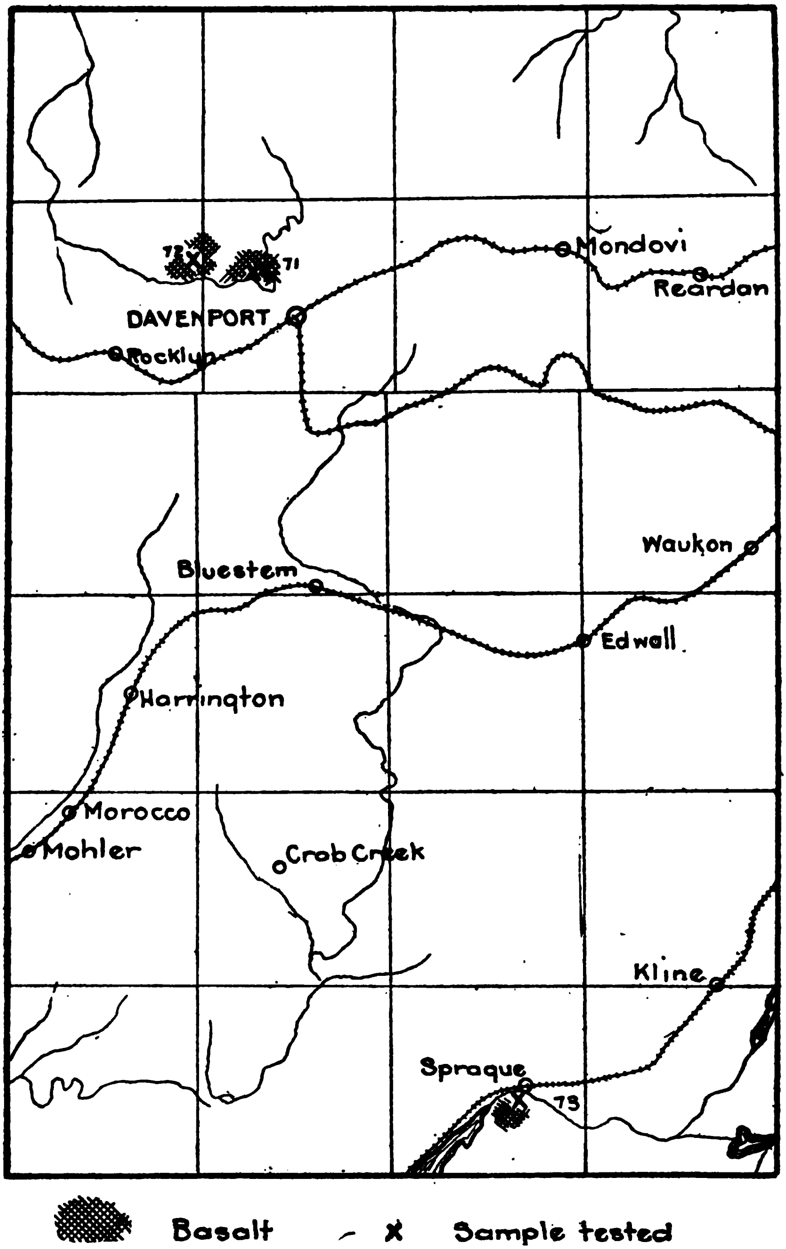
LINCOLN COUNTY.

GENERAL STATEMENT.

This county is located toward the eastern margin of the state, but about equidistant from the north and south boundaries. It forms a part of the great lava plateau of southeastern Washington, and varies from 1,500 feet to 2,000 feet above sea level. On the northern boundary of the county the plateau breaks off very abruptly into the canyons of Columbia and Spokane rivers. The slope of the plateau is almost wholly southward into the drainage of upper Crab creek.

About all of the underlying rock of the county is basalt. The rock beneath the basalt flows has been uncovered along some of the deeper canyons, as may be seen along Columbia and Spokane rivers. Over the uplands the bed-rock does not commonly appear except along the walls of the larger coulees. The wagon roads and railways commonly follow the coulees and so a means of transportation is generally afforded when the rock is needed. The basalt varies greatly in character from place to place, and even in the same locality. Some of the flows of lava are too porous to be serviceable. Usually lava sufficiently free from steam holes to be valuable for road building may be found along any coulee wall where there are large outcrops.

The annual rainfall of the county varies from 10 inches in the lower portions to 15 inches over the higher parts. The



EASTERN PART OF LINCOLN COUNTY.

Scale, 1 inch equals 6 miles.

precipitation comes chiefly in spring and it is only at that season that the small streams are active. Only the larger streams have a permanent flow and all the others are intermittent in character. It is in general a treeless country, the chief exception being the scattering growth of conifers along the eastern and northern margins. It was originally a bunch grass region but all the arable portions of the county are now in wheat fields. The farms are large and as long as wheat raising continues to be the chief industry it is not likely that the county will increase in population except at a very slow rate. The towns are small and growing slowly. Outside of a few trunk lines it is not likely that many roads will be surfaced with crushed rock for some years. The basalt is generally of a good quality and quarries to supply crushed rock can be had sufficiently near together to keep the cost of transportation within reasonable limits. There is a general absence of gravel convenient for road use, and so crushed rock will needs be depended upon for road material when first-class highways are constructed.

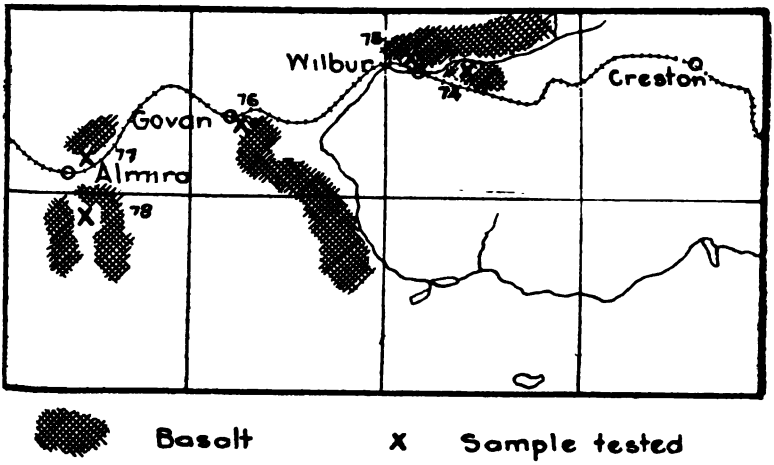


FIG. 29. Part of Lincoln county, around Wilbur.
Scale, 1 inch equals 6 miles.

ROAD MATERIALS TESTED.

Serial Number 71.

The country around Davenport is gently rolling and there are few outcrops of rock. About 2 miles northwest of the town, in the NE¼ of Sec. 18, T. 25 N., R. 37 E., 100 feet north of the wagon road, there is a basalt ledge along the side of the creek. The ledge has an 8-foot face or cliff of rock and a small talus slope. The surface rock is somewhat weathered and porous, but the quality improves within the ledge. A sample was procured here and sent to the laboratory to be tested. It was found to be a fine-grained, brown-black porous basalt; a rather soft rock with low toughness, average resistance to wear, and fair cementing value. If used in road building it should make a satisfactory material.

Serial Number 72.

West of the above locality, about 3½ miles distant from Davenport, this sample was taken. At this point, on the north side of the creek, a basalt cliff is located about 100 feet northeast of the wagon road. The basalt cliff continues in a northeast direction for several hundred feet. The face of the cliff varies from 4 feet to 15 feet in height, with a long slope of broken rock at the bottom. A thin layer of soil overlies the rock. The surface of the rock is much weathered, but there are only a few steam holes. A sample was secured at a point about 250 feet northeast of the road. When tested the rock was found to be a fine grained, gray-black basalt, very hard and tough, with average resistance to wear and good cementing value. As crushed rock it should make a very good road material for heavy traffic.

Westerly from Davenport there is no rock along the railway track until a point is reached about 4 miles southeast of Fellows; from here onward for 5 miles there are many mesa-shaped areas of porous basalt lava, with low cliffs from 5 to 20 feet high. There are also many small knolls and knobs of basalt containing an abundance of steam holes.

Easterly from Davenport the railway passes through an almost level country in which there are very few outcrops of rock. There is a 5-foot ledge of basalt exposed on the south side of the track in the eastern part of Reardan, and another about half way between that town and Mondovi.

Serial Number 73.

This sample was taken from a ledge one mile southwest of Sprague. The locality is away from the railway about one mile and is now reached only by wagon-road. There is here a ridge of basalt 800 feet long and 20 feet or so in height. The ridge is bare on top, as well as along its western face. The rock occurs in columns about 18 inches in diameter, standing vertically. The basalt is very hard and has a sharp shell-like fracture in small specimens. Larger blocks have a tendency toward plane surfaces. In the laboratory this rock was found to be a fine-grained, gray-black basalt, hard and tough. It has high resistance to wear and fair cementing value. It should produce a crushed rock which could be used successfully in road building. Considerable rock has been quarried here and used in Sprague for foundation work. Numerous ledges of very similar rock, from 5 feet to 10 feet in height, occur along the railway from one-half to one and one-half miles southwest of Sprague.

Serial Number 74.

Extending first easterly and then northerly, from Wilbur to Sherman, there is a small coulee with basalt walls for almost its entire length. A sample was taken from a cliff in the S.W.¼ of Sec. 9, T. 26 N., R. 33 E., about one-half mile north of the railway and very near a county road. The cliff has a perpendicular face of 15 feet, with a long slope of broken rock at its foot. It is covered with a very thin veneer of soil. It is a heavy fine-grained, dense gray-black basalt, emitting a metallic sound when struck. There are no steam holes in the rock at this point. According to the test that was made this is a hard, tough rock with high resistance to wear and fair cementing value. For macadamizing work it should yield satisfactory material.

Serial Number 75.

The town of Wilbur is bounded along the north side by a low rampart of basalt from 5 to 15 feet in height, with a steep slope of broken rock at the foot of the cliff. There is very little overburden in the way of soil. The rock is fine-grained, blue-black, and contains quite abundant small steam holes. The rock that was tested from this point showed average resistance to wear and good cementing value. Although it was not tested for hardness and toughness it is believed that it would make a satisfactory road material. West of Wilbur for about 1½ miles small ledges of basalt crop out in which the steam holes are very abundant.

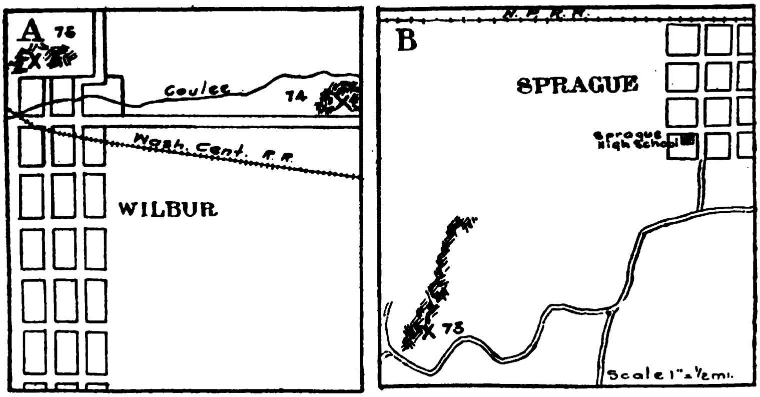


FIG. 30. A—Some basalt ledges at Wilbur. B—Basalt cliffs near Sprague.

Serial Number 76.

Extending in a southeasterly direction from Govan for several miles there is a coulee with terraced sides and perpendicular faces of basalt having a maximum height of 40 feet. About one-half mile east of Govan, between the wagon road and the railway, there is a cliff and slope of broken rock extending east and west for several hundred feet. The perpendicular face of basalt, about the broken rock, varies in height from 2 feet to 8 feet. There is only a very light overburden. The cliff is less than 100 feet from the wagon road, and only a little further from the railway. The rock is a compact, heavy, gray-black basalt, with very few steam holes. According to the test made upon the sample secured here the basalt is a hard, tough rock, with high resistance to wear and fair cementing value. It is best suited for roads having heavy traffic.

Between the wagon road and the railway, about one and one-half miles east of Govan, there is a pit of gravel made up of well rounded pebbles of basalt. That part of the highway beginning one-half mile southeast of the town and extending southeasterly for a mile or more has been surfaced with gravel from this pit. On the roadway the pebbles have cemented together fairly well.

Serial Number 77.

Three-fourths of a mile northeast of Almira there is a railway cut 150 feet long with a maximum depth of 10 feet. The wagon road is close by on the south. There is but little soil above the rock. A sample was taken from the fresh rock in the cut. The test showed it to be a heavy, dark gray basalt, with a few small steam holes. It is a hard, tough rock, with high resistance to wear and fair cementing value. If used as a road material it would be best suited for highways having heavy traffic.

Serial Number 78.

One mile south of Almira a coulee begins which extends in a southerly direction for many miles, affording large exposures of basalt. In this coulee about one and one-half miles south of Almira, in the SE¼ of Sec. 4, T. 26 N., R. 31 E., there is a perpendicular wall of basalt 35 feet or more in height, on the east side of the coulee. The wall is apparently made up of three flows of lava. On top there is a layer 15 feet thick of dark basalt, containing many small steam holes, and overlaid by a few inches of soil. The second layer, also about 15 feet thick, exhibits many vertical columns from 1 to 2 feet in diameter. The rock of this flow is compact, dark and heavy, with very few steam holes. The lower flow is almost wholly concealed by the great mass of broken rock at the base of the cliff. A sample was taken from the columnar rock of the second or middle lava flow. As tested it is a fine grained, gray-black, porous basalt, hard and tough, with high resistance to wear and good cementing value. It has all of the qualities that go to make up an excellent road material. A wagon road runs past this cliff, on its way to Almira, but with a rather steep grade for a part of the way.

MASON COUNTY.

GENERAL STATEMENT.

The northern portion of this county, that from Hood's Canal westward, lies within the Olympic mountains. The foot-hills come down to tide-water on the east, and merge into the higher parts of the Olympics on the west. The eastern and southern parts of the county are regions of low relief, covered with broad plains and low hills. The streams of the highlands flow in deep valleys, sometimes canyons, with sharp and high divides between them; the streams of the lowlands have little velocity and wide valleys, with broad interstream areas.

There are very few outcrops of rock in the county, outside of the mountains. The lowlands have glacial deposits everywhere as their surface coating. These consist mostly of beds of till and gravel. Both of these materials make satisfactory roads where the travel is light. Some of the gravels bind together well, and have been known as "cement gravel." The till, consisting of pebbles cemented by clay, makes good roads where the grades have been properly established and the drainage is good. There are many gravel plains within the county where the roads are always good. Many miles of county road have been gravelled, with satisfactory results.

The best rock deposits suitable for yielding crushed stone, and which are convenient for transportation, are located along Hood's Canal. While some of this rock is only fairly good, there are certain deposits which may be used with good results. It is reported that southwest of Shelton, near Cloquallum, on a logging railway, there are basalt cuts from 10 to 30 feet in depth. Some of this rock has been used along the railway for riprapping. No samples were secured at these outcrops for testing.

The annual rainfall of the county varies from 60 inches to 85 inches. This insures a rank forest growth almost everywhere. The only exceptions to a heavy stand of timber have been the highest mountain slopes and some of the gravel prairies where the soil is very coarse. The industries dependent upon the forests have always been the principal ones. With the removal of the forest agriculture is securing a foot-hold where the soil conditions are best. The agricultural population is steadily increasing. Macadamized roads will soon be necessary, especially where the traffic is heaviest or where no satisfactory material save crushed rock may be had for highway construction.

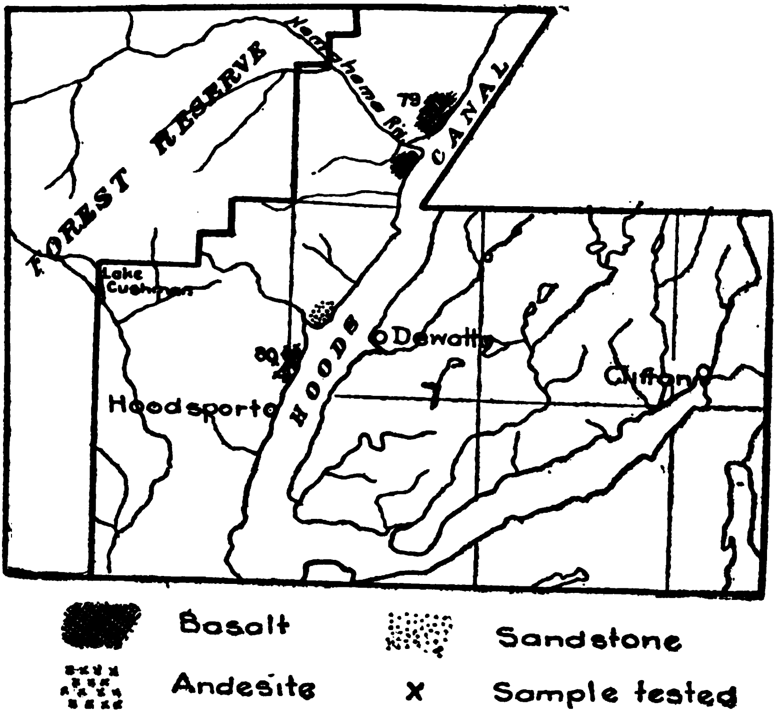


FIG. 31. North central part of Mason county.
Scale, 1 inch equals 6 miles.

ROAD MATERIALS TESTED.

Serial Number 79.

About one mile north of the mouth of the Hamahama river there is a gently sloping hill with a steep cliff on the east side. The foot of the cliff is lapped by the waters of Hood's Canal. There is a face of rock exposed about 40 feet high and several hundred feet long. There is another cliff of rock out-cropping above the first and perhaps 40 feet further back, with a gently sloping terrace between them. A sample was taken from the lower ledge. According to the test it is a porous, greenish gray, decomposed basalt, in which the steam holes have become filled with secondary minerals. It is a rather soft rock, with average resistance to wear, low toughness, and excellent cementing value. Although the test made upon the rock showed that it is of poor quality in some respects, yet upon the whole it might be regarded as a satisfactory road material. The rock is located convenient for transportation since scows may be anchored alongside the cliff at any stage of the tide.

Serial Number 80.

About 2 miles north of Hoodsport, on the property of Mr. John Sund, there is a little cliff of rock at the foot of a hill on the west shore of Hood's Canal. In a quarry which was once operated here there is a face of rock 25 feet high. An attempt was once made to make paving blocks out of the rock but it proved to be too soft. A sample was taken of the best rock in the quarry. As determined by the laboratory test the rock is a medium grained, light greenish gray, fragmental andesite, or in other words an andesite breccia. It is a rather soft rock with low toughness, average resistance to wear, and excellent cementing value. If used for highway construction it is best suited for roads subjected to light traffic. It is near the water's edge, and scows may be floated almost up to the ledge. Similar rock is exposed at other points northward along the shore.

OKANOGAN COUNTY.

GENERAL STATEMENT.

Okanogan county is a very large one, embracing within its borders a great variety of topography. The western end of the county lies within the highest parts of the Cascade mountains; the eastern end forms a part of what has been called the Okanogan Highlands. Two broad valleys cross the county from north to south, viz., those of Okanogan and Methow rivers. A high divide separates these valleys. Along the eastern margin of the county, extending from north to south, there is a mountain ridge of gentle slopes, having a general height of 4,000 feet above the sea.

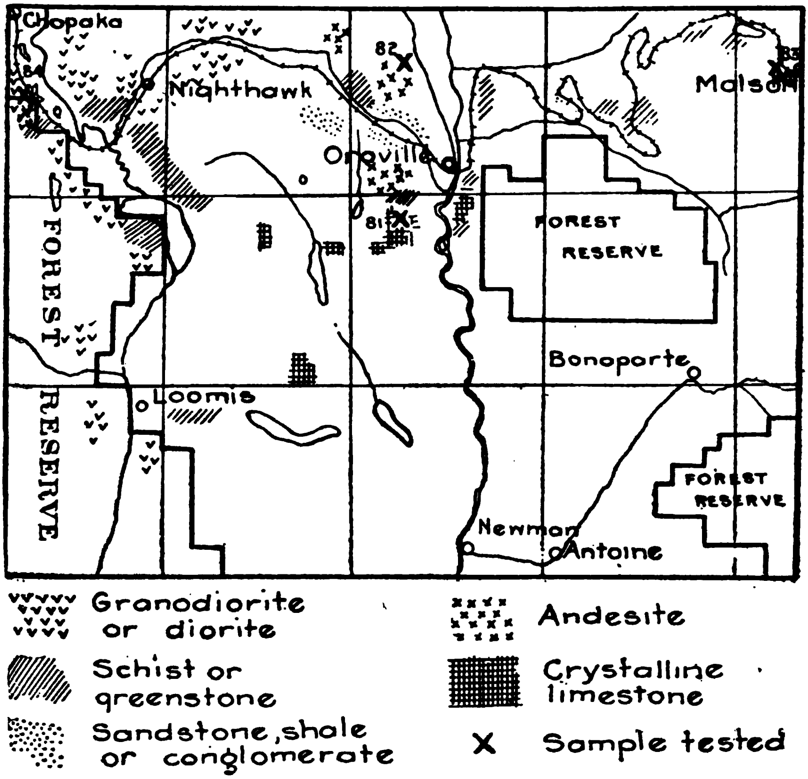


FIG. 32. North central part of Okanogan county.
Scale, 1 inch equals 6 miles.

The rock formations of the county exhibit a very great variety. The rocks of the higher mountains are generally granite, gneiss, schist, slate, quartzite, etc. Limestone, or marble, occurs at many places in the northern part of the county. Dikes and flows of basalt and andesite are found at many places in different parts of the county. The latter rocks yield the best material for macadamizing roads. Some of the limestone might also be used where the traffic is not too heavy. In all the larger valleys there are extensive glacial deposits, usually occurring as benches or terraces along the valley walls. These may be drawn upon for road materials upon the local highways or where the travel is not too heavy. Samples were secured only in the northeastern portion of the county, along the line of railway. No effort was made to study the road materials in detail off the lines of easy transportation.

The precipitation per year varies in amount from 20 inches and more in the highlands to less than 10 inches along the deeper valleys. The region of least rainfall is that along the Okanogan river. Agriculture cannot be very successfully carried on in the Okanogan and Methow valleys without irrigation. In both valleys the soil is good, the water supply ample, and in a few years they will support large agricultural communities depending upon irrigation. The future road building will be in the thickly populated portions of these valleys and smaller ones. Except for some work done upon the state road in the Methow valley the highways of the county have been but little improved.

ROAD MATERIALS TESTED.

Serial Number 81.

Two miles southwest of Oroville, and one-fifth of a mile west of the county road, there is a limestone cliff over 100 feet in height, from the foot of which a sample was collected. The limestone is compact and massive, with a color ranging from blue-gray to white. It is entirely crystalline and wholly changed to marble. Some of it appears to be rather siliceous. It is a part of a limestone or marble area covering at least 2 square miles. A sample was collected and tested in the hope that it might prove to be a useful road material. It was not tested for hardness or toughness, but is known to be low in both these particulars. It has low resistance to wear and fair cementing value. It is not recommended as a road material. Limestones also occur east of Oroville, and a lime-kiln was operated there some years ago.

Serial Number 82.

Three miles northwest of Oroville, on the west side of Osoyoos lake, and one-eighth mile west of the county road there are large exposures of rock. They occur on the east face of Kruger mountain and are some hundreds of feet high in all. The lower part of the slope is more or less covered with masses of broken rock. A sample was collected from the broken rock at the base of the mountain. According to the test it is a grayish green, highly altered andesite, composed of large crystals of feldspar and hornblende in a groundmass of very fine crystals. It is a very hard rock with average toughness, high resistance to wear and fair cementing value. It should make a satisfactory road material. Rock similar to this occurs on the hill one mile west of Oroville.

Serial Number 83.

About one-half mile west of the railway station at Molson there is a small hill or knob of marble covering approximately 5 acres. At the north end of this hill there is a steep cliff with a face 125 feet high. There is practically no overburden on any part of this little hill. A "Y" extends from the main track to within 300 feet of the base of the hill. The rock is massive and no bedding planes can be distinguished. It is finely crystalline and has a color varying from cream to light blue-gray. Some of the marble is siliceous, and there are frequent lenses and veins of quartz. A sample was taken from the northeast end of the cliff, near the top. As tested the marble has average hardness, low toughness and fair cementing value. It was not tested for per cent. of wear. It is possible that it might be used satisfactorily on roads subjected to light traffic.

Serial Number 84.

At the Ruby mine, about 3 miles south of Chopaka station, there are large cliffs of rock. A spur track extends from the railway to the mine, alongside the cliffs. The rock has a medium to coarse grained granitoid texture and the minerals which compose it may be readily recognized. The color of the rock changes from light to dark as the mineral ingredients vary. The test made on the sample collected demonstrated that the rock is a coarse grained diorite containing both orthoclase and plagioclase feldspars and is technically a granodiorite. It is a hard rock, with rather low toughness, average resistance to wear, and low cementing value. It is only suitable for the foundation course in plain macadam construction.

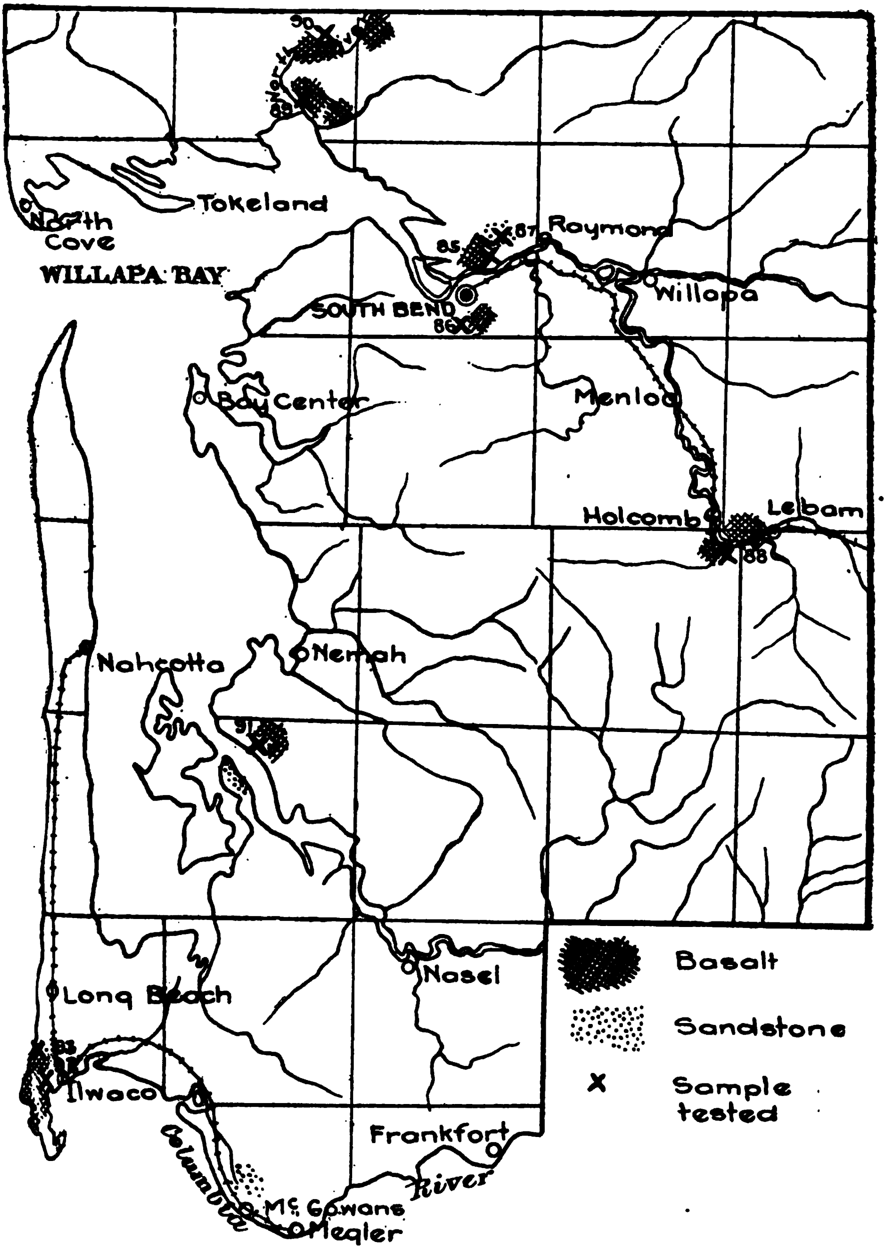
PACIFIC COUNTY.

GENERAL STATEMENT.

This county occupies the extreme southwestern corner of the state. It borders on both Columbia river and the Pacific ocean. The shore line is very irregular, abounding in deep indentations and projecting sand spits. The surface slopes gradually upward from the water level to the crest of the Coast range, which has a maximum height of 3,000 feet above the sea. Marshy conditions prevail along much of the shore line and in the lower river valleys. Broad alluvial valleys extend from tide-water well into the low mountains.

A deep mantle of soil covers nearly all parts of the county so that rock outcrops are comparatively rare. The underlying rocks are prevailingly sandstone, shale and conglomerate, with occasional thin lenses of limestone. Dikes of basalt occur rather frequently, usually forming low knobs or hills. The sedimentary rocks noted above are worthless for road use and the only bed-rock available is the basalt. Some of the basalt is too soft to be serviceable, but the most of it is capable of yielding crushed rock of good quality.

There are no glacial deposits within the county and hence a general absence of beds of till, gravel and sand. There are



WESTERN PART OF PACIFIC COUNTY.

Scale, 1 inch equals 6 miles.

some gravel bars along the larger streams and along the ocean beach. Some of the highways have been surfaced with gravel and a beginning has been made in the construction of macadamized roads.

The rainfall is so heavy that originally all the land surface of the county was heavily forested. A very large percentage of the forest remains uncut. In the Willapa valley, along the Columbia, and adjacent to the sea shore a good many farms have been cleared so that from this time on agriculture will be an increasing industry. With the development of agriculture there will come the necessity for a system of improved highways. Much of the transportation of the county is by water. The principal roads constructed thus far have been in the Willapa valley, from South Bend eastward.

ROAD MATERIALS TESTED.

Serial Number 85.

About one mile northeast of South Bend, at the narrows of Willapa river, and on the north bank of that stream, there is a basalt ridge several hundred feet long. A small quarry was once developed where the ridge closely borders the river. A face of rock was exposed about 12 feet high, the foot of which is about 25 feet above the level of the stream, with a steep slope of broken rock between the cliff and the beach. The overburden of soil amounts to about 7 feet. A sample was taken from the center of the quarry for the laboratory examination. It proved to be a fine grained, greenish black basalt, rather soft, with low toughness, average resistance to wear, and excellent cementing value. If the hardest portions

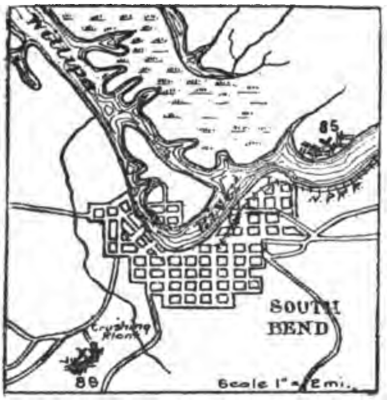


FIG. 33. Location of the basalt quarry near South Bend.

of the rock are selected for use it should make a very good road material.

Serial Number 86.

One mile south of South Bend, in the SE¼ of Sec. 32, T. 14 N., R. 9 W., the county has purchased 3 acres of land for a quarry and crushing plant. At this place basalt outcrops along the walls of a deep ravine. The quarry will soon have a face about 300 feet long and 50 feet high. An overburden of 3 feet of soil must be removed. The rock crusher is operated by a traction engine. The top of the crusher is on a level with the quarry floor; a chute 45 feet long extends from the crusher to the bins below; a down grade haul carries the rock out to the county road. A sample of the crushed rock when tested was found to be a porous, light gray, fine grained basalt. It possesses average hardness and resistance to wear, low toughness and low cementing value. It should make a satisfactory road material. The rock is used in surfacing the state and county roads of that vicinity.

Serial Number 87.

One and one-half miles northwest of Raymond and about one-half mile north of Willapa river there is a bluff of rock approximately 600 feet high. At one point, on the property of the Raymond Land and Improvement Company, some blasting has been done to determine the character of the rock. In this way a face nearly 40 feet high has been made. A sample was selected from the freshest rock at the face and according to the laboratory test it is a fine grained, light greenish gray, thin bedded standstone. It is a soft rock with low toughness, rather low resistance to wear, and good cementing value. It does not have the necessary qualities to make a proper road material.

Serial Number 88.

Between Lebam and Holcomb, and at a locality 1½ miles southeast of the latter place, rock is exposed in several cliffs on both sides of the river. In constructing its line the railway company changed the course of the river here and this point is commonly known as "Channel Change." On the south side of the railway, in Sec. 1, T. 12 N., R. 8 W., the railway once operated a quarry and used the rock for fills, rip-rap, etc. A bold face of rock was developed about 300 feet long and 50 feet high. The county road, which is only a few hundred feet south of the track, passes over this hill by a steep grade. The mass of rock consists of coarse angular greenish fragments in a more compact dark groundmass. It is a very soft rock and easily falls to pieces under the weather. Much of it can be easily cut with a knife. A sample for testing was taken of the best rock. It is a fragmental basalt, or basalt tuff, with low toughness, average resistance to wear, and excellent cementing value. It is so soft that it should only be used on the nearby roads, or those where the traffic is very light.

Serial Number 89.

There are several basalt cliffs between the mouth of North river and the crossing of the Chehalis county line. On the east side of the river, near the mouth, in the SE¼ of Sec. 26, T. 15 N., R. 10 W., basalt is exposed for 1,000 feet or more along the bank. The rock makes a cliff from 10 to 30 feet high, overlaid by from 2 to 6 feet of soil. The rock has a gentle slope toward the river, and it would probably be necessary to work back into the hill for 200 feet or so to secure a vertical face of 75 feet. A sample was secured near the south end of the cliff. According to the test the rock is a fine grained, gray-black basalt, free from steam holes. It has average hardness, rather high resistance to wear, low toughness and excellent cementing value. It should make a satisfactory road material. It is conveniently located for water transportation.

Serial Number 90.

About 3 miles from the mouth of North river, in the SE¼ of Sec. 14, T. 15 N., R. 10 W., on the west bank, there is a ledge of basalt varying from 5 to 10 feet in height. The hill comes down to the river with a slope of about 25 degrees. Some of the rock is much weathered and very soft. A sample was taken of the fresher rock just above the water. In testing the rock it was found to be a medium grained, greenish black basalt.

It is rather soft, with low toughness, average resistance to wear and excellent cementing value. It should make a good road material. This ledge of rock is very similar to all that found in this vicinity, on both banks of the river.

Serial Number 91.

At the mouth of Nasel river, on the north side, near the center of Sec. 4, T. 11 N., R. 10 W., back from the beach a little way, the bank is covered with large angular blocks of rock, which hide the ledge itself. The exact amount of rock here was not determined, but it is believed to be large. A sample was taken from some of the larger blocks. According to the test the rock is diabase, with substantially the same composition and qualities as basalt. Not enough rock was taken to determine in the laboratory the resistance to wear, hardness or toughness. It has a low cementing value. It may safely be recommended as a fairly good road material.

Serial Number 92.

Between Ilwaco and Fort Canby some low cliffs of basalt occur along the water's edge. Immediately south of Ilwaco, on a little cove, there is a promontory 75 feet or more in height, with a 20-foot face of basalt exposed back from the beach at the foot of the hill. A sample was taken from the foot of the ledge. The test shows that the rock is a fine grained, gray-black basalt, rather soft, with low toughness, average resistance to wear, and good cementing value. It should make a satisfactory road material under light traffic.

Serial Number 93.

At Ocean View, near Ilwaco, there is a large basalt cliff facing the westward. It is a long cliff, varying from 30 feet to 150 feet in height. In general it has an overburden of 10 feet of soil. The rock is greatly weathered and altered. A sample was taken from the foot of the cliff, near the water's edge. The test proved the rock to be a very dense, fine grained, dark gray basalt. It has low hardness, toughness, and resistance to wear. It has excellent cementing value, and should make an excellent material for roads having light traffic.

PIERCE COUNTY.

GENERAL STATEMENT.

Pierce county extends from tide-water on Puget Sound to the summit of the Cascade mountains, and hence has a great diversity in topography. The western part of the county is a broad lowland having an average height of 400 feet above tide. The eastern third of the county is wholly within the higher mountain ranges and peaks of the Cascades. The middle section of the county is occupied by the wooded foot hills that form the interstream divides.

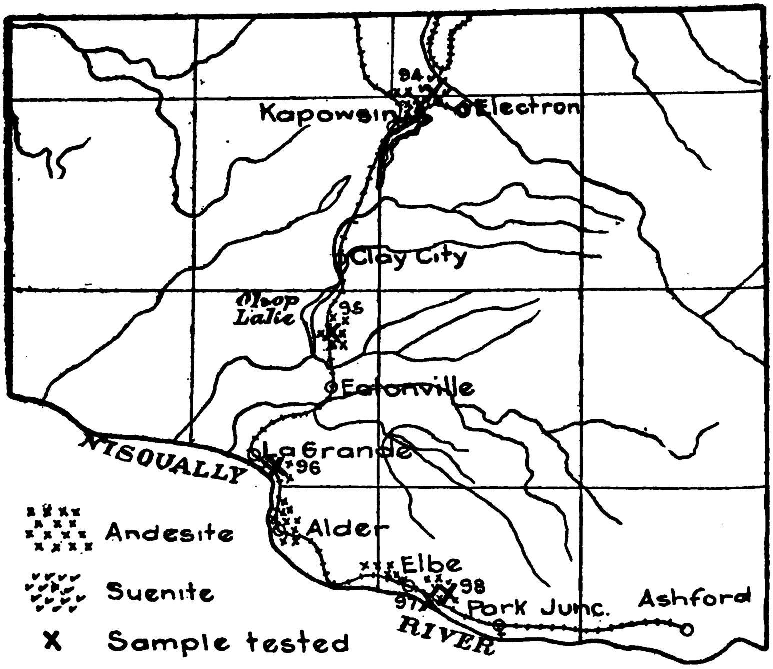


FIG. 34. South central part of Pierce county.
Scale, 1 inch equals 6 miles.

The bedrock of the county is made up in part of sedimentary rocks and in part of igneous rocks. The sedimentary rocks are usually sandstones and shales, with workable coal seams at some localities. These rocks are of no value in road building except that some of the harder sandstones have been used in the manufacture of paving blocks. The igneous rocks are much the more abundant of the two classes. They include great lava flows as well as the deep-seated rocks such as granite and syenite. The varieties of rock which are most convenient for transportation and which may be utilized in road building are certain deposits of andesite and syenite. Unfortunately the great bulk of igneous rocks are not situated where they may be drawn upon for road use.

When the bedrocks are traced from the mountains westward they sink below the heavy mantle of glacial sediments and wholly disappear. All over the lowlands of the county the till and gravel deposits of glacial origin are very abundant. The gravels occur as wide-spread plains or prairies; the till is usually found in the low terraces or ridges that are densely wooded. Good roads are easily made over the great gravel plains and a little grading is all that is usually necessary. The drainage is easily cared for because of the very porous character of the subsoil. Over the gravel prairies the surface streams are very few, the drainage being practically all underground.

Except for the cities and towns the population of the county is largely limited to the rich alluvial valleys, such as that of the Puyallup. Here the forest has been cleared away and intensive farming is carried on with excellent results. The farms are small and the density of population will soon require well-ordered systems of good roads. Already some roads have been given a permanent character by a proper grading, and the use of crushed rock from a quarry owned by the county. In other instances the roadways have been surfaced with gravel as a temporary expedient. Over the gravel plains, where the population is scant, it will doubtless not be necessary to use crushed rock in road-building except along the trunk highways.

ROAD MATERIALS TESTED.

Serial Number 94.

This sample is from the quarry belonging to Pierce county, about one and one-fourth miles from Kapowsin, on the railway spur to Electron. At this point a bold hill of rock rises above the track, having very little overburden. The steep face of the hill adjacent to the railway is about 500 feet long and over 100 feet high. The rock at the surface is very little weathered and fresh material may be readily quarried. The crushed rock is used by the county in the construction of macadamized roads. The rock is a fine grained, dark colored syenite. A sample was tested in the highway laboratory of the University of Washington. According to this test the rock is hard, with moderately high resistance to wear; it is low in toughness, with good cementing value. The toughness is not so low as to be a serious objection. The worst feature is the extreme hardness of the rock which prevents the formation of fine materials under wear. This may make the surface slow in binding, especially for water-bound macadam.

Serial Number 95.

This sample was taken from a hill west of Ohop Station, something over 2 miles north of Eatonville. There are hills of similar rock in this vicinity, and along the railway toward Eatonville. Some of the hills are bare, while some are covered with a heavy overburden of soil. None of the hills exceed 60 feet in height. The rock is dark in color, with light colored crystals scattered through the groundmass. It is very much jointed and is deeply weathered along the joint planes. Some stripping is necessary in order to secure firm, solid rock. A specimen was collected of the freshest rock that could be found at the surface. As determined by the test the rock is a highly altered andesite, rather hard, with average toughness and resistance to wear, and good cementing value. If the weathered stone were rejected and only the fresh rock used it should make an excellent road material.

Serial Number 96.

About one mile east of La Grande the county road runs parallel to the railway, but about 150 feet above it. Along the upper side of the highway there are several outcrops of andesite, granite, and other rocks, the basalt being much in excess of all others. The andesite in its principal outcrop occurs as a cliff about 50 feet high. It is situated in a convenient position to be loaded onto railway cars. A sample of the rock was taken for a laboratory examination. According to the test it is a very fine grained, steel gray, highly altered andesite. It is a very hard and tough rock with high wearing value and fair cementing value. It should make an excellent road material especially under heavy traffic.

Serial Number 97.

This specimen is from a hill just east of Elbe, near the bridge across Nisqually river. The hill is about 50 feet high, nearly bare, and quite steep. The rock occurs in columns 12 inches in diameter which stand in a vertical position. A sample was taken of the columnar rock for testing. The result showed a grayish black rock made up of a very dark ground mass and containing small white crystals of feldspar. It is a hard andesite, with low toughness, and average resistance to wear. It has good cementing value and should marke a fairly satisfactory road material.

Serial Number 98.

This sample was taken from a hill a few hundred feet east of the locality just described. Its occurrense is very similar except in this case the hill is about 75 feet high. The rock is of a dark gray color when unweathered, hard, somewhat brittle, and much jointed. The rock weathers somewhat easily and breaks roughly but without sharp edges. It is an andesite of a porphyritic character. Although not tested for these qualities it is known to be brittle rather than tough and of only medium hardness. It offers low resistance to wear and has good cementing value. It would not be wise to use it in road building.

SAN JUAN COUNTY.

GENERAL STATEMENT.

This county is made up of a group of islands which is located between the mainland and Vancouver island. The largest islands are San Juan, Orcas and Lopez. These islands have been formed by a sinking or subsidence of the land whereby the sea has come in and filled the lowlands. The former hills and divides have been converted into islands and the valleys into bays, sounds, channels and straits. The present topography consists of low plains, rolling uplands, rounded hills and low mountains. The shore-line is everywhere greatly indented and irregular. It presents a constant succession of small promontories and shallow bays.

As a rule the mantle of soil is thin over the islands so that bedrock is close at hand. The shores are rocky almost everywhere, and about all the elevations outcrops of rock are of general occurrence. The bedrock presents a wide variety in kind and character. In the northern portion of the islands, notably Waldron, James, and Sucia, the prevailing rock is sandstone. It is quarried for various purposes; much of it is made into paving blocks. The bulk of the bedrock of the islands belongs to the metamorphic division, such as crystalline limestone, schist, slate, and quartzite. In addition to the above there are intrusions or dikes of various types of igneous rocks, such as granite, basalt, etc. For road building purposes several of these types of rocks may be utilized, and their distribution is such that the haulage need not be great. Gravel is almost wholly lacking, at least in its general distribution, and so this material can not be relied upon for road surfacing.

Because of the smallness of the islands and the abundance of waterways the roads are short and much of the necesary transportation is by water. The climate and soil of the islands have been found to be particularly desirable for fruit growing. This will lead to intensive farming and in time to a large population. A system of first-class highways will be necessary to connect shipping points with the orchards. To this time but little has been done in the matter of the construction of permanent roads.

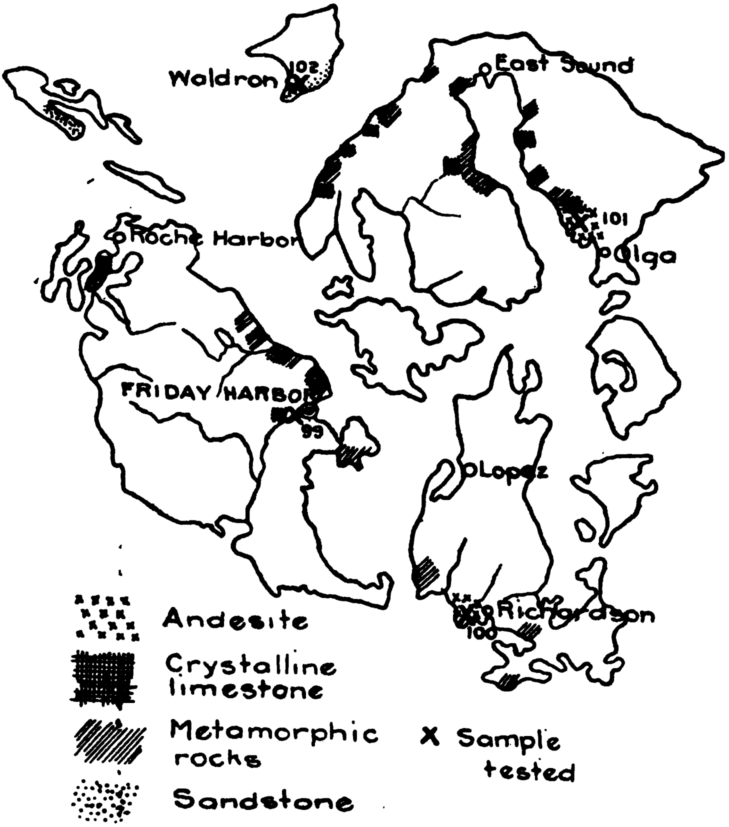


FIG. 35. Map of San Juan county.
Scale, 1 inch equals 6 miles.

Serial Number 99.

About one-fourth mile west of Friday Harbor there is a little hill 50 or more feet in height, with a cliff on the east side having a maximum height of 35 feet. All told the hill is several hundred feet long. The county road has been blasted through this rock for a short distance. It is in the main a dark bluish gray, compact rock, breaking with an even to sub-conchoidal fracture, and giving sharp splintery edges. Some of it is schistose and foliated, much altered, stained and impregnated with iron oxide. A sample was selected from the more compact rock in the ledges along the county road. According to the test it is a quartzite, more or less impure. It is a hard, rather tough rock, with somewhat high resistance to wear and excellent cementing value. It should make a satisfactory road material.

On the south side of the peninsula southeast of Friday Harbor there are some low ledges and cliffs of metamorphic rocks. They vary from compact, greenish blue, silicious rock to foliated ferruginous schists. All the rock is very much fractured and broken. On this peninsula there are areas thickly strewn with glacial boulders of granite, gneiss, schist, and other rocks. Some of the erratics are in the form of angular masses as much as 12 feet in diameter.

On the northwest shore of San Juan Island, at Roche harbor, there is a large outcrop of limestone over 200 feet in height. The rock is massive and the bedding planes wholly destroyed. It is a light colored to bluish, compact limestone. At this place the Tacoma and Roche Harbor Lime Company has a very large lime-burning plant. The limestone was not tested for its value as a road material.

Serial Number 100.

Rocky ledges form the shores for much of the way around Lopez island. At Richardson, on the southwest shore of the island, the ledges are exposed in low cliffs which do not exceed 25 feet in height. The overburden of soil is very light. A sample was taken near the wharf at Richardson. As proven by the test the rock is a light greenish gray, fine grained, compact, highly altered andesite. It is a hard, tough rock, with high resistance to wear and excellent cementing value. It should make an excellent road material.

Serial Number 101.

On Orcas island, a little way northwest of Olga, there is a hill several hundred feet high. It rises from the shore of East Sound, with a steep slope and rocky ledges all the way from the water's edge to the summit. The rock varies much in character from place to place. Some of it is compact and massive, while some of it is laminated and schistose. Usually the rock is much cut up and broken by joints and fractures. A sample was collected at a point about one-half mile west of Olga, and approximately 50 feet above the water. As proven by the test it is a medium grained, dark greenish gray, highly altered andesite. It is a rather hard rock, with average resistance to wear and toughness, and good cementing value. It should make very good road material.

Rock outcrops very generally around the shores of East Sound. Some of the rock is similar to that noted above, and some of it is limestone. Many low ledges of rock outcrop around the shores of West Sound also. On the west side of Deer harbor there is a perpendicular rock cliff over 100 feet high rising from the edge of the water. It is known locally as "glass rock." It is a very hard, coarse grained, vitreous quartzite, in which the pores among the whitish quartz grains have been completely filled with glassy looking quartz.

Serial Number 102.

Much sandstone is exposed along the southern coast of Waldron Island. At one place a quarry is operated by the Northwest Contract Company. In the quarry a face of rock is exposed several hundred feet long, with a maximum height of 200 feet. At the west end of the quarry the basal rocks are conglomerate and coarse sandstone, while the upper rock is fine grained sandstone. A sample was selected from the upper beds at the west end of the quarry. As determined by the test the rock is a feldspathic sandstone. It is a soft rock with low toughnes, average resistance to wear, and fair cementing value. It should not be recommended as a road material in plain macadam construction. The rock is used for jetty rock on

Gray's Harbor, and is also made into paving blocks and used on Seattle streets.

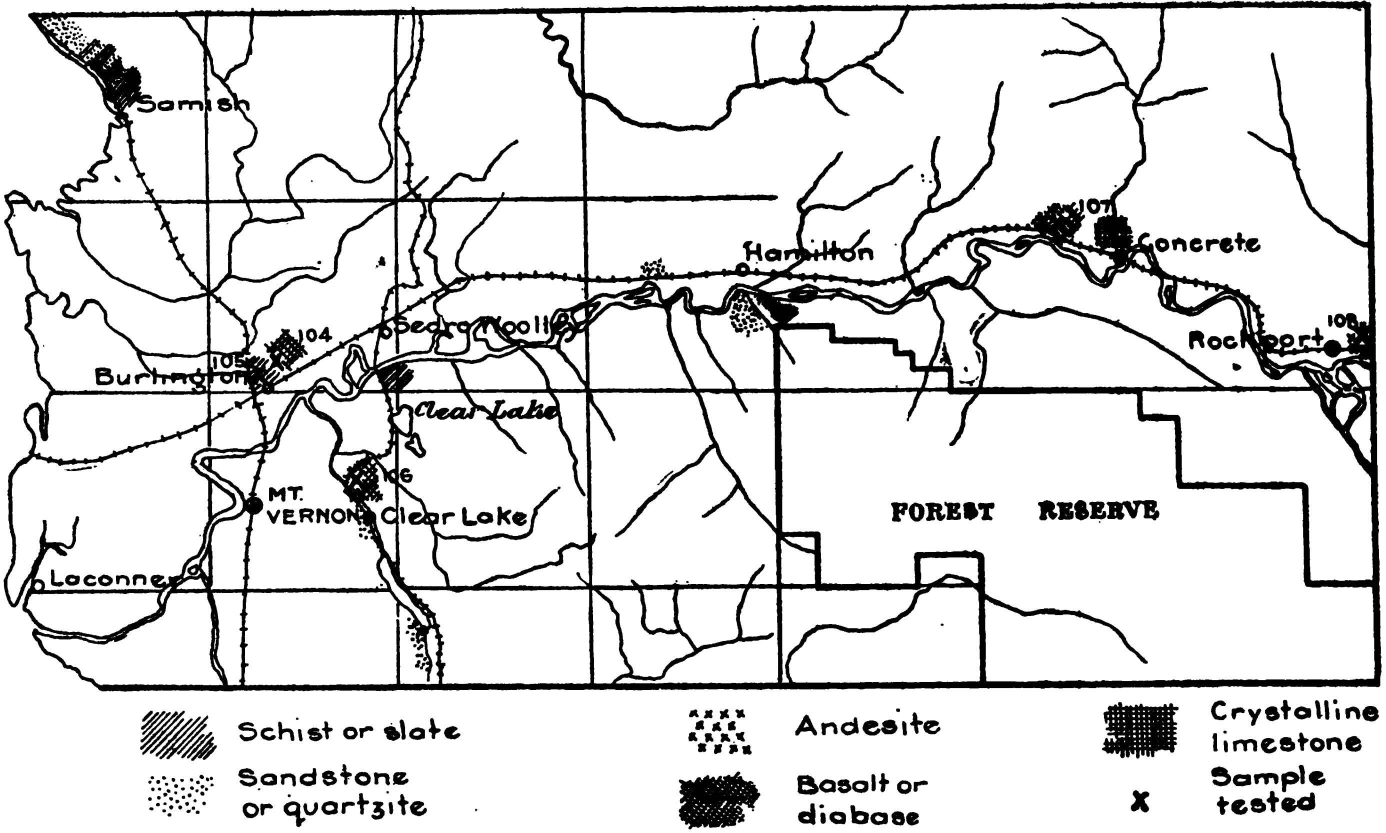
SKAGIT COUNTY.

GENERAL STATEMENT.

Skagit county is over 100 miles long by 24 miles wide, and extends from the sea to the summit line of the Cascade mountains. The shore line is very irregular and is characterized by headlands, bays, and islands. Adjoining the shore there is the great delta of Skagit river which makes up a conspicuous lowland. The eastern two-thirds of the county lie within the Cascade mountains, which are deeply cut by the valleys of the Skagit and its tributaries.

The prevailing rocks of the county are schists, slates, crystalline limestones, and other metamorphic varieties. Lying above these at several places there are true sedimentary rocks, such as sandstones and shales. In some instances the latter contain coal seams, as at Hamilton and near Sedro-Woolley. Occasionally there are dikes of andesite and basalt, which have been forced up through fissures from below. It is the latter kinds of rock that must needs be drawn upon for road material. The other varieties of rock are as a rule so lacking in hardness and toughness that they are not satisfactory. In some cases, as at the Fidalgo quarry on Deception Pass, a sandstone may have the necessary composition and physical properties to make useful macadam material. Gravel occurs at several places, mainly as terraces along the Skagit valley. In some places it is accessible for use, and has been employed in surfacing roads.

The principal towns and settlements of the county are within the lower Skagit valley. The soil here is of remarkable fertility, capable of supporting a large population. The principal highways will be those running radially from the shipping centers to the farming communities. The amount of traffic is such that many of these roads should be macadamized as early as possible. The distribution of good material is such that the haulage of crushed rock from quarry to roadway need not be for a long distance, or involve unusual expense.



Scale, 1 inch equals 6 miles.

WESTERN PART OF SKAGIT COUNTY.

ROAD MATERIALS TESTED.

Serial Number 103.

This sample was taken from the state quarry, located on the extreme southern end of Fidalgo island, at the eastern entrance of Deception Pass. This is known as the Fidalgo quarry. At this locality the rock rises very boldly from the sea, attaining a height above tide of over 400 feet. There is a slight reentrant or bay which has provided a good site for a crushing plant and insured quiet water for the moving and loading of scows. The transportation of the stone must be wholly by water. The water is sufficiently deep so that scows or vessels may come in and load at any time. The rock cliff is so steep that there is but little broken rock as a covering, and the vegetation is limited to a few trees. The rock is but little weathered at the surface and no stripping is necessary in quarry operations. The extreme height of the cliff makes a gravity crushing plant entirely feasible, and permits of a minimum cost of operation.

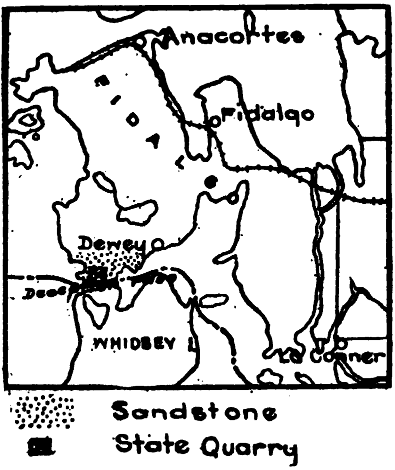


FIG. 36. Fidalgo Island and state quarry.

The rock is of sedimentary origin but has been rather highly metamorphosed. It occurs in layers or strata, having a general east and west strike and a very steep northward dip. The natural joints in the rock are of sufficient number to cheapen the quarry operations and yet not yield too many flat surfaces among the crushed rock. It breaks with a conchoidal fracture and possesses very sharp edges. According to the test made upon it the rock is a dense, fine grained, greenish gray sandstone, composed chiefly of orthoclase feldspar, and the secondary minerals, chlorite and epidote. It is a hard rock, with medium toughness, rather high resistance to wear, and good cementing value. It should give satisfactory results when used as a road material.

At Fidalgo quarry the state has installed a crushing plant consisting of a rock crusher, revolving sorting screen, storage bunkers, and scow loader. The rock crusher is an Austin Number 6, rated at a crushing capacity of sixty tons of rock per hour, producing broken rock as large as two and one-half inches in diameter. The revolving screen sorts the crushed rock into three sizes. The storage bunkers consist of five bins with a combined capacity of 1,600 cubic yards. Each bin has two spouts for discharging its contents. The scow loader is a movable belt conveyor which transfers the rock from the bins to the scows. It has a capacity of 100 cubic yards of broken rock per hour. The rock is transported in large scows and used in the construction of state and county roads in those counties adjoining Puget Sound.

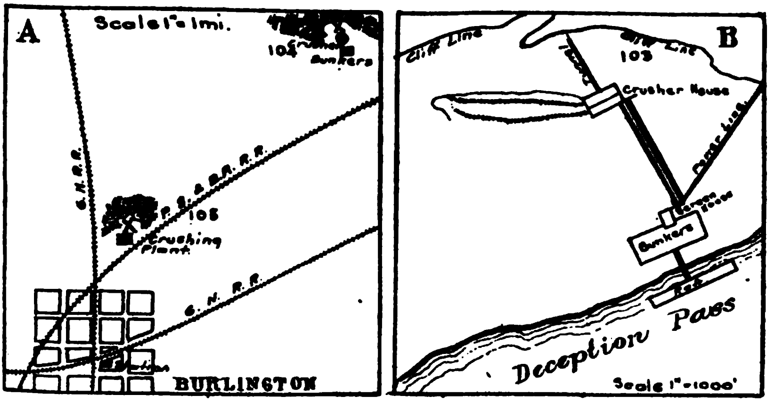


FIG. 37. A—Some quarries and crushing plants near Burlington. B—Plan of quarry and crushing plant at state quarry on Deception Pass.

Serial Number 104.

About two miles northeast of Burlington there is a small, isolated, bare rock hill, surrounded by a broad, low plain. The maximum height of the hill is 300 feet, and about its sides are steep cliffs of rock. On the south side of the hill the county owns one acre of land and operates a quarry. The quarry is located at the foot of a steep, almost perpendicular cliff about 125 feet high. The amount of overburden is a mere trifle. The amount of available rock is very great. The rock is generally compact and massive, but some of it is schistose. Small lenses and stringers of quartz frequently occur. The sample that was taken proved to be a fine grained, grayish green, highly altered basalt. It is a hard, tough rock, with high resistance to wear and fair cementing value. It is recommended especially for those roads that have a heavy traffic.

The crushing plant at the quarry is operated by a traction engine. The rock has been used on about 4 miles of the county road between Burlington and Sedro-Woolley. Some of it has been down for several years and it is said to have proven satisfactory.

Serial Number 105.

About one-half mile north of Burlington there is a small hill with a maximum height of 200 feet. It has very little soil covering, thus affording numerous rock exposures. On the south side of the hill, at the edge of town, a small quarry has been opened. The quarry is operated where there is a cliff about 150 feet wide and 50 feet high. A sample was taken from the quarry and tested. According to the laboratory examination the rock is a fine grained, steel gray, schistose slate. It is a soft rock with low toughness and fair cementing value. It is of too poor a quality to be used as road material.

A crushing plant is operated in connection with the quarry. The floor of the quarry is high enough so that the rock is dropped into the crusher. After breaking it is lifted by conveyors to the screen and bins. The rock is being used in surfacing the streets of Burlington. It is dumped upon the streets and left to be packed down by use. The rock as seen on the streets appears to be very inferior in both wearing and cementing qualities, giving a muddy surface in wet weather and a dusty surface in dry weather.

Serial Number 106.

Along the railway, about 2½ miles south of Clear lake, there are 2 small hills of rock. The smaller one has the better rock and is nearer the railway. It is located about 200 yards east of the track. The hill is an isolated mass of rock about 200 feet in diameter and 75 feet high. The rock is mainly bare of soil and is but little weathered. A sample was taken from the foot of the cliff nearest the county road. As determined by the test it is a fine grained, light greenish gray, highly altered diabase. It is a hard, rather tough rock, with high resistance to wear, and good cementing value. It should make a very satisfactory road material. The opportunity for opening a quarry here is good. For rail connection it would require a spur track about one-fourth of a mile in length, on a gentle downward grade to the quarry.

Serial Number 107.

About 3 miles west of Concrete a railway cut 500 feet long has been made through rock. On the north side of the track there is a vertical face of rock nearly 60 feet high. A second ledge 8 feet thick is exposed back of this, on the wagon road, at a height of 150 feet above the track. All the rock is much broken by joint planes. The appearance of the rock varies somewhat within short distances. The sample that was taken proved to be a medium grained, dark grayish green, highly altered diabase. It is a very hard and tough rock, with average resistance to wear and good cementing value. This rock should make a very good road material.

North of Concrete, along the canyon walls of Baker river, there are large cliffs of crystalline limestone. One mile north of the railway bridge across Baker river, and on the east side of the stream, a face of limestone over 200 feet high is exposed. Material is taken from these localities for the manufacture of Portland cement at the two factories near the mouth of Baker river.

One mile east of Faber there is a rock cut on the railway about 1,000 feet long, and from 10 to 50 feet in depth. The rock is of a dark color, but is not uniform in character. It is all rather brittle and easily shattered. Much of it is schistose, while some of it is finely granular to compact. No sample was taken for testing.

Serial Number 108.

Rockport is situated on a bench above Skagit river, and is hemmed in by high mountains on the north and northeast. About one-fourth of a mile east of the town a ledge of rock is exposed along the wagon road. The rock outcrops continuously for 150 feet lengthwise, with a height to the ledge varying from 10 to 30 feet. Other outcrops occur on the slope above, which steepens rapidly to the northeast. The surface rock is much jointed and fractured, and largely weathered. A sample was secured at a point along the highway where some blasting had been done, and where the rock was freshest looking. According to the test it is a greenish gray, highly altered andesite. It has average hardness and toughness, low resistance to wear, and good cementing value. It should be satisfactory to use in the construction of roads having light traffic.

Along the railway track, in the vicinity of Samish, there are many outcrops of soft rock, mainly schist. The rock is often talcose in character, and is always soft. Adjacent to the railway, one-fourth of a mile south of Samish, there is a ledge over 50 feet high. Back of this there are other cliffs on the steep hillside which would give a total thickness of at least 240 feet. The state road occupies a shelf above the railway, where the solid rock is being excavated. A sample was collected of this fresh rock but it was lost in shipment.

SKAMANIA COUNTY

GENERAL STATEMENT.

This is one of the counties that has a frontage on Columbia river. Except for a fringe of hilly, broken land along the river the entire county is one of high mountains. From east to west almost the entire width of the higher Cascades is embraced within the county. About one-half of Mount Adams and nearly all of Mount St. Helens are included within the county boundaries.

But little is known of the rock formations of the county. Along Columbia river the only rock is basalt. It has been produced in former ages as a series of lava flows. On the canyon walls along Columbia river several of these flows may be seen in a cliff or a series of cliffs. The rock is black and hard, generally porous, but sometimes dense and compact. It is frequently jointed in such a way that it stands in columns—usually in a vertical position, but sometimes curved in fantastic shapes. The basalt occurs in such abundance that quarry sites, convenient for the transportation of the crushed rock, and where the quality of the material is first-class, may be readily found. Gravel occurs very sparingly, generally in bars along the river which are uncovered at the lowest stage of water.

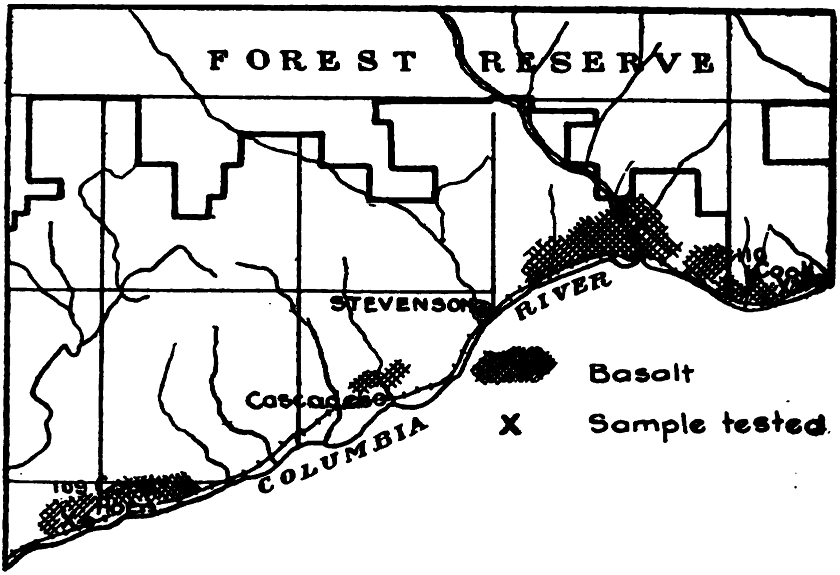


FIG. 38. Southern part of Skamania county.
Scale, 1 inch equals 6 miles.

The people of the county live along Columbia river and in the small tributary valleys. The forest once grew everywhere and but little of it has been cleared away. Fruit growing has been begun and in time that will probably be the chief agricultural industry. The transportation at present is very largely by water and rail. But few roads have been constructed as yet. When the time comes for macadamized highways the county will be fortunate in the abundance of first-class road material which it has at its command.

ROAD MATERIALS TESTED.

Serial Number 109.

This sample is from the east side of Cape Horn, a bold promontory on the north bank of the Columbia 30 miles from Vancouver. Cliffs of basalt from 150 to 200 feet high extend eastward from Cape Horn for some distance. Columnar structure is conspicuous, the columns being small and jointed, so that the rock is readily removed in small pieces. The rock is compact and nearly free from steam holes. The cliffs are quite bare of soil or vegetation and rock may be economically removed and shipped either by rail or water. Good quarry sites are common and the amount of good rock practically unlimited. According to the test the rock is a dense, fine grained, gray-black basalt. It is a very hard, tough rock, with rather high resistance to wear and fair cementing value. It is recommended as a very good road material.

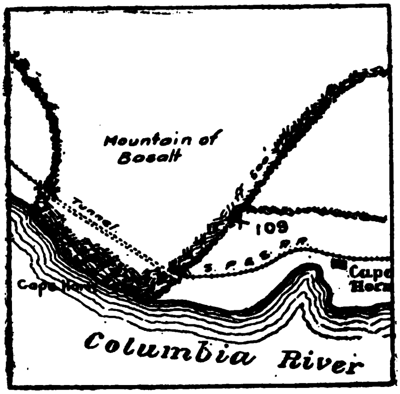


FIG. 39. Basalt cliffs near Cape Horn.

Serial Number 110.

Cliffs reaching a maximum height of 500 feet occur between Ash and Cook. Near the latter place the cliffs are vertical, from 100 feet to 300 feet in height, and bare of soil or other covering. A sample was secured at the base of a cliff one-fourth mile west of Cook. The rock is more massive than that at Cape Horn and less easily removed; but it is equally dense and hard. The locality affords an excellent quarry site. As determined by the laboratory examination this rock is a very dense, fine grained, gray-black diabase. It is a hard, tough rock, with high resistance to wear, and excellent cementing value. It should make a first-class road material.

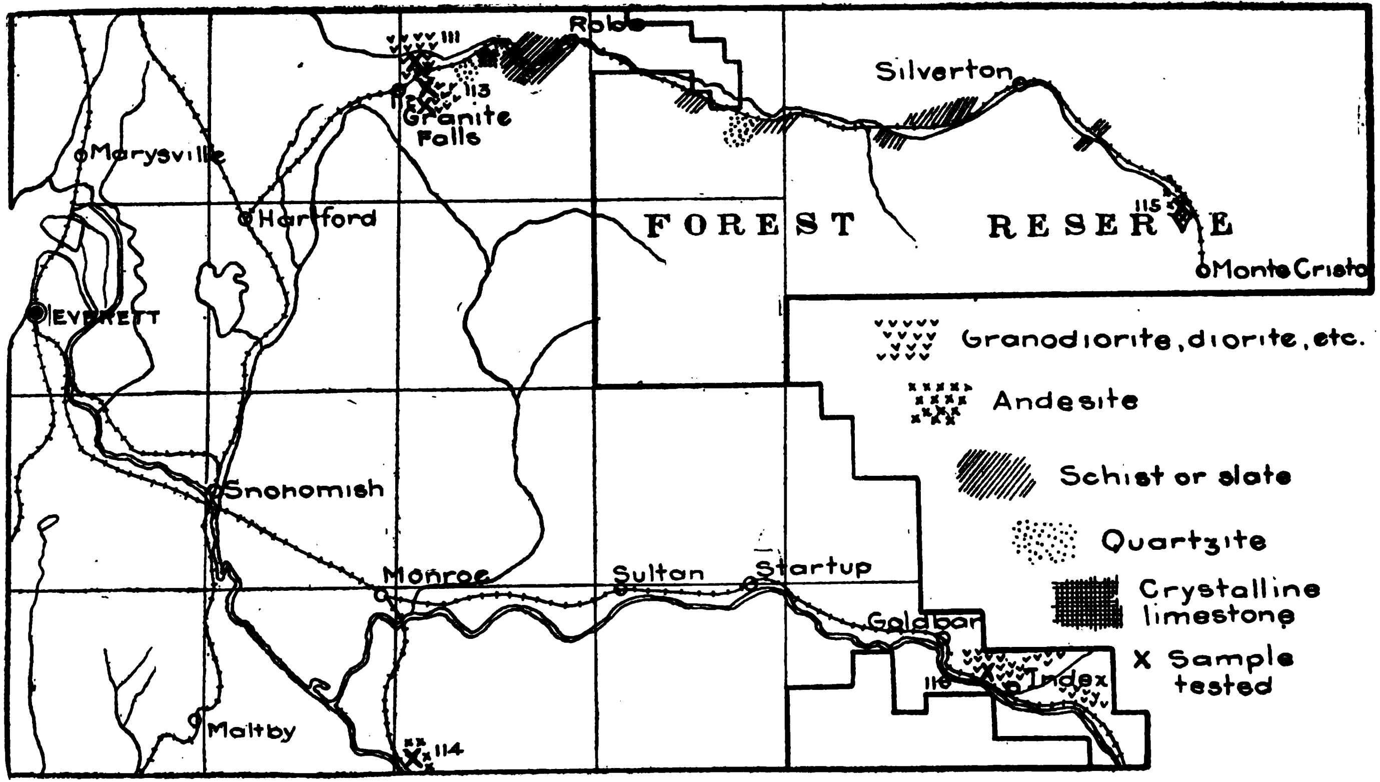
Basalt similar to that just described occurs east of Cook at several points. One locality is 2 miles away, at tunnel Number 2, where there is a hill 75 feet high. A second occurrence is in a railway cut 4 miles east of Cook. The latter locality affords a face of rock 40 feet high, with a good opportunity to increase it by quarrying northward into the hillside.

SNOHOMISH COUNTY.

GENERAL STATEMENT.

As measured by townships this county has an east and west extent of over 60 miles, and a north and south frontage on tidewater of over 36 miles. The western end of the county has a lowland topography, varied by terraces, low ridges and hills. The eastern two-thirds is a very mountainous country, rising gradually from the west until the summit line of the Cascades is attained. The mountains are trenched by the great valleys of Skykomish river and the two forks of Stillaguamish river, which have general east-west courses.

Outcrops of rock seldom occur in the lowlands of the western part of the county. The bedrock here is deeply covered under glacial deposits, mainly till and beds of gravel and sand. Both of these are utilized in road making and are fairly good where the volume of traffic is not large. Rock outcrops in abundance in all the mountainous portions of the county. As observed along the valley walls the prevailing rocks are schists, slates, quartzites, and crystalline limestones or marbles. Into these several kinds of igneous rocks have been intruded, such as granite, diorite, andesite, and basalt. Rocks belonging to the last class are the most desirable ones to use in road building.



Scale, 1 inch equals 6 miles.

WESTERN END OF SNOHOMISH COUNTY.

Fortunately they occur at enough places so that the length of haul need not be great in supplying crushed rock for any road within the county. Probably material from Fidalgo quarry can be furnished to roads near tidewater at less expense than it can be obtained at any locality within the county.

In the past the lumber industry has been the chief one within the county. The logged-off-lands are now receiving attention and their agricultural possibilities determined. The chief farming communities are in the broad alluvial valleys where the soil is excellent. The agricultural population has become so large that a system of good roads through the country has become necessary. Main lines of first-class highways connecting the larger towns are imperative. The county has now reached that stage of development when a well designed system of macadamized roads should be planned at once, and constructed as rapidly as possible.

ROAD MATERIALS TESTED.

Serial Number 111.

One and one-fourth miles northeast of Granite Falls, in the S. E. ¼ of Sec. 7, T. 30 N., R. 7 E., there is a small hill about 150 feet high. On the south side of this hill there is a quarry which is connected with the railway by a spur track one-fourth of a mile long. The face of rock in the quarry is about 50 feet long and 40 feet high, but the rock is exposed for at least 400 feet along the south side of the hill. On the slope above the quarry a couple of ledges appear. The overburden of soil on the slope varies in thickness, but is very thin on the rim of the quarry. A sample was secured of the fresh rock from the quarry. By test it is a coarse grained, greenish gray diorite. It is a hard rock, with average toughness, high resistance to wear and fair cementing value. If used for highways it would be best suited for roads with heavy traffic.

Serial Number 112.

A portion of the southeast ¼ of section 18, T. 30 N., R. 7 E., located southeast of Granite Falls, has been purchased by the county as a quarry site. It has been planned to use the rock from this quarry as road material. There are no extensive outcrops and the surface rock is much weathered. The rock is a soft black serpentine which can be readily cut with a knife. When rubbed it takes on a gloss or polish. It was so soft that the sample was not tested for hardness or toughness. It has low resistance to wear but excellent cementing value. Material of this kind cannot be recommended for use in road building.

Serial Number 113.

About one mile east of Granite Falls is a hill known as Iron mountain. It is located in sections 18 and 19, T. 30 N., R. 7 E. The summit of the hill is 1,085 feet above sea level and about 650 feet above the nearby railway track. The hill has gentle slopes with occasional outcrops of rock. A portion of the hill, owned by Mr. J. L. Snethen of Granite Falls, is almost all overlaid by diorite. This property has been leased to the Pacific Coast Granite Company of Everett. The company intends to quarry the stone for building purposes, street paving blocks, and monumental rock. At the surface the rock is much weathered and considerable stripping will be necessary to secure desirable stone. The sample that was tested proved to be a coarse grained, light gray diorite. It is a hard rock, with average toughness and resistance to wear, and fair cementing value. It should make a fairly satisfactory material for road construction.

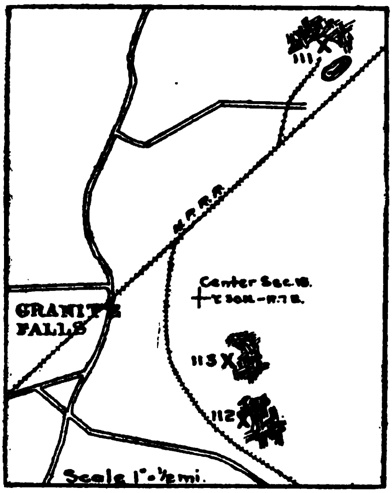


FIG. 40. Rock outcrops and quarries at Granite Falls.

Serial Number 114.

From Monroe south to Cherry Valley there is a good graveled road much of the way. Near the county line, and about 1,000 feet north of the C. B. Shingle Mill there is a rock cut along the east side of the highway. The principal rock exposure is about 150 feet long with a maximum height of 20 feet. There is very little soil covering but the rock is weathered to a depth of several feet. The sample that was tested proved to be a light gray, highly altered andesite, porphyritic in character. It possesses average hardness and resistance to wear, low toughness, with good cementing value. It would be desirable to use such rock only on roads having light traffic.

Serial Number 115.

This sample was taken from the foot of a cliff 1½ miles north of Monte Cristo, and not far from Barlow Pass. The cliff is adjacent to the railway track and has a height of 125 feet. According to the test the rock is a fine grained, dark grayish green, highly altered andesite. It originally contained steam holes which have become filled with chlorite, epidote, and calcite. It is a hard rock, with high wearing value, low toughness, and fair cementing value. It has the qualities of a good road material.

Serial Number 116.

One-half mile west of Index, along the railway track, there is a very large granite quarry owned by J. A. Soderberg, of Seattle. At this place there is a great cliff of granite, forming the south face of the mountain. The rock is unusually free from joints and very large masses are quarried out from the cliff. The stone is extensively used for street curbing, paving blocks, and as a building and monumental stone. A sample of the rock was selected and tested for its value as a road material. According to the results of the test it is a coarse grained, light gray rock composed essentially of plagioclase feldspar, dark green hornblende, quartz and orthoclase. Technically it is defined as a granodiorite. It is a hard rock with low toughness, average resistance to wear, and fair cementing value. It would be suitable only for the foundation course in plain macadam construction.

SPOKANE COUNTY.

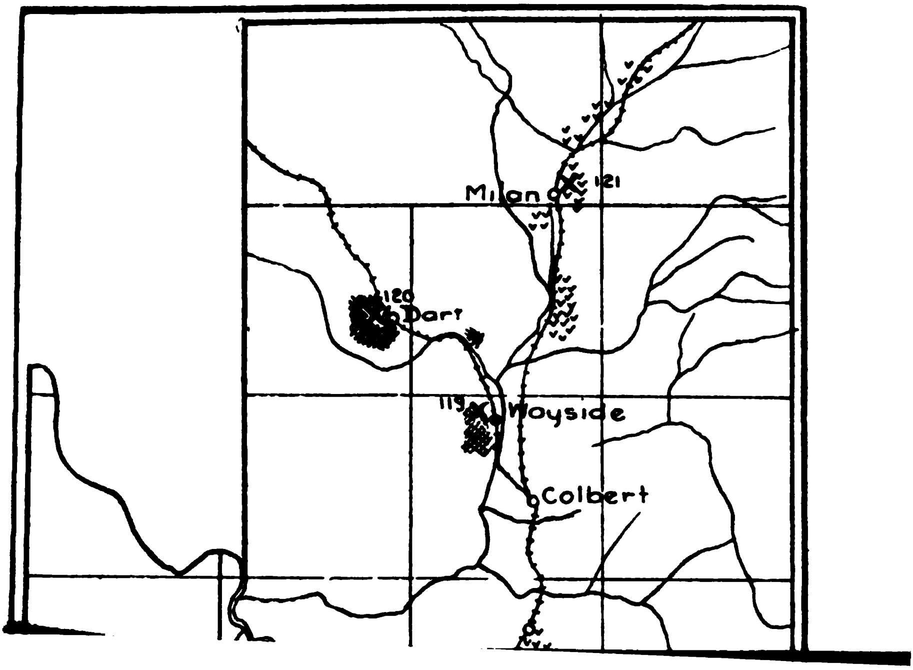
GENERAL STATEMENT.

Spokane county is located on the eastern margin of the state. The eastern half of it contains numerous foothills and low mountains of the Rockies; the western half extends into the basalt plateau of the Columbia. The hills and mountains are characterized by rounded forms, and precipitous slopes are uncommon. The plateau is surfaced by rolling hills and occasionally trenched by small canyons. The chief stream of the county is Spokane river. East of the city of Spokane the valley of this river is broad and level floored; northwest of the city the river flows in a canyon which continually deepens as the Columbia is approached.

The rock formations of the mountains of the county are mainly granite, schist, and gneiss. The prevailing rock of the plateau is basalt. There are many places where the originally thin covering of basalt has been stripped away by erosion and a floor of granite or schist uncovered. The granite and similar crystalline rocks project westward as promontories in a sea of basalt. The lava in its outflows has entered many of the mountain valleys and formed re-entrants of basalt extending eastward into the granite and its associates. In the western part of the county there is usually a deep soil covering so that outcrops are not numerous.

There are two classes of road materials which may be had in the county, viz., crushed rock and gravel. Basalt of good quality may be found at so many points that it should be the rock most used. Tests were made upon the granite of several localities, as enumerated below. Gravel of excellent quality occurs in the Spokane and smaller valleys. It is mostly of granitic origin and make a satisfactory material for surfacing roads that have a light traffic.

The suburban population of Spokane county has become so large that improved highways are now very necessary. As a rule the making of first-class roads will not be difficult because


121
Milan
120
Dart
119
Wayside
Colbert

of the simple grades, the good drainage, and the abundance of road material of a high quality.

ROAD MATERIALS TESTED.

Serial Number 117.

About one mile north of Hillyard, near the crossing of the Great Northern railway by the county road, there is a basalt ledge. This outcrop is on the east side of the track, about 50 feet higher than the railway, near the foot of a hill. At the base of the ledge there is a slope of talus 100 feet in length, which extends almost to the highway. A thin veneer of soil covers much of the basalt. There are a few steam holes but not enough to destroy the value of the material for road use. A sample was secured by breaking up several large blocks at the foot of the talus slope. As determined by the test the rock is a fine grained, grayish brown, highly weathered basalt. It is a hard, tough rock, with high resistance to wear and fair cementing value. It should make a very good road material.

Serial Number 118.

One mile north of Hillyard, and very near the locality last described, the railway passes through several small granite cuts, with from 4 to 12 feet of rock exposed. About 400 feet east of the railway, near the bottom of a hill, a ledge is exposed alongside the highway. A little quarry has been opened here and blocks of granite have been taken out. A sample was secured from some of the quarried blocks. It is a coarse grained, gray granite; a very hard rock, with low toughness, average resistance to wear and fair cementing value. It is not recommended as a suitable road material.

Serial Number 119.

A mile northwest of the station at Wayside, and just east of the railway, Dragoon creek flows through a small gorge about 150 feet long. On the east side of this gorge there is a cliff of basalt 35 feet high. From this locality southward for 2 miles or more basalt is of common occurrence, generally in the forms of knobs and domes. A sample was collected from a knob directly across the track from the section foreman's house at Wayside. According to the test it is a fine grained, grayish black basalt. It is a hard, tough rock, with high resistance to wear and very low cementing value. As a road material it is only suited for the foundation courses in macadam construction.

Serial Number 120.

West of Dart, at a distance of 600 feet from the railway, a ridge of basalt parallels the track for over 3,500 feet. The ridge is about 100 feet high, with frequent cliffs ranging from 10 to 30 feet in height. At the foot of the ridge there is a long slope of broken rock. A marsh lies between the basalt ridge and the railway. A few small steam holes occur in the rock. A sample was collected from the broken rock at the base of the ridge. As demonstrated in the laboratory the rock is a fine grained, gray black, porous basalt. It is a hard rock, with average toughness, high resistance to wear, and low cementing value. It should make a satisfactory road material.

Serial Number 121.

On the east side of the railway at Milan there is a long ridge of rock several hundred feet high. The rock is much weathered and it is difficult to secure fresh rock. A sample was secured from a 30-foot ledge which is exposed about 300 feet east of the station. According to the test the rock is a greenish gray, highly decomposed porphyritic granite. Although not tested for these qualities, it is known to be of average hardness and low toughness. It has average resistance to wear and good cementing value. It is only of fair value as a road material.

Serial Number 122.

This sample was secured from the state quarry 1½ miles south of Marshall. It is situated in the SW¼ of Sec. 27, T. 23 N., R. 42 E. The quarry connects by means of a short spur track with the Palouse branch of the Northern Pacific railway. The quarry is located on the face of a cliff about 100 feet in height. The rock is basalt, much jointed, compact, and free from steam holes. It is so little weathered that the surface rock is very fresh. The overburden consists of a thin layer of soil, with a scattering growth of trees. The test, made of a sample collected from the large broken blocks at the foot of the cliff, proved the rock to be a dark gray, fine grained basalt. It is a hard, tough rock, with high resistance to wear, and low cementing value. It should make a satisfactory road material.

The equipment which is being installed at this quarry consists of a rock crusher, elevator, revolving sorting screen, and a storage bunker. The crusher is an Austin No. 6, rated at 45 cubic yards per hour. The storage bunker consists of 5 bins with a combined capacity of 412 cubic yards. The crushed rock is to be used in macadamizing the state and county roads in this and neighboring counties.

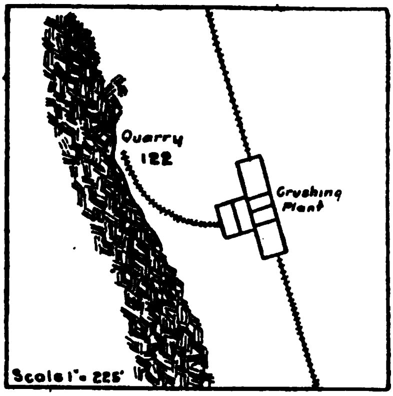


FIG. 41. Plan of state quarry and crushing plant at Marshall.

Serial Number 123.

Immediately west of Marshall, in the NE$\frac{1}{4}$ of Sec. 21, T. 24 N., R. 42 E., there is a hill 100 feet or more in height. The east slope is almost wholly covered with a talus of broken rock. Above the broken rock a cliff varying from 5 to 20 feet in height is exposed, with very little overburden. The county road and the Spokane, Portland and Seattle railway pass by the foot of the hill. Much of the rock abounds in steam holes, but at some points they are few in numbers. A test of the sample taken demonstrated that the rock is a fine grained, grayish black basalt. It is a hard rock, with low toughness, and fair cementing value. If carefully selected in quarrying it should make a satisfactory road material.

Serial Number 124.

This sample was secured from a cliff of basalt 1½ miles northeast of Marshall. The cliff is located in the NE¼ of Sec. 14, T. 24 N., R. 42 W., on the Spangle road, about one-third of a mile south of its junction with the Marshall-Spokane highway. The cliff is several hundred feet long. At its top there is a rock face 40 feet high with a broad and steep talus slope at the base which extends to the road. The rock breaks with a conchoidal fracture and sharp edges. It is compact, with very few steam holes. According to the laboratory test made upon it the rock is a fine grained, dark steel gray basalt. It is a hard, tough rock, with low cementing value. It should make a satisfactory road material.

Serial Number 125.

One mile northeast of Cheney, in Sec. 7, T. 23 N., R. 42 E., the Northern Pacific and the Spokane, Portland and Seattle railway tracks are side by side, the latter being in a cut 30 feet below the former. This cut exposes a face of rock from 10 to 30 feet in height and over 1,000 feet long, with very little or no overburden. Some of the rock is worthless as a road material because of the high percentage of steam holes. In other places the steam holes are not so numerous as to interfere with the general quality of the rock. A sample was collected of the best appearing rock, and upon testing proved to be a dense, fine grained, gray black basalt. It is a hard rock with low toughness and excellent cementing value. If a quarry is located where the rock is best the material may be used satisfactorily in macadam construction.

Serial Number 126.

About 1½ miles east of its station at Medical Lake the Northern Pacific railway passes through a rock cut 150 feet long and five feet deep. The rock is a medium grained, dark gray basalt, free from steam holes. It is hard and tough, and breaks with a shell-like fracture. When tested it showed average resistance to wear and low cementing value. It should make a satisfactory road material.

Serial Number 127.

At the west side of the north end of Silver lake, near the town of Medical Lake, a granite quarry is operated by J. W. Morris. The rock receives a beautiful polish, and is made into monuments. A sample was collected from this quarry. According to the test it is a light gray, coarse grained granite. It is a hard rock with average resistance to wear, low toughness and fair cementing value. It is not recommended as a road material, except in the foundation course.

On the west shore of Medical Lake there is a granite quarry operated by Alfred Giles. It is located at the foot of the hill below the state hospital for the insane. In the quarry there is a face approximately 150 feet long and 30 feet high, and the bottom of the quarry is below the surface of the lake. The rock is quarried for building stone and mounnments. It is very similar to the granite last described.

Serial Number 128.

This sample was taken from a cut along the Spokane, Portland and Seattle railway, near the south line of Spokane. The cut is over 500 feet long, with a maximum depth of 25 feet. In the cut there is a stratified light colored clay overlaid by basalt. The basalt is heavy, massive, and free from steam holes. It is fine grained, and light gray in color. When tested it was found to have average hardness, but is a little low in toughness. Although it is low in cementing value, it should make a fairly satisfactory road material.

Serial Number 129.

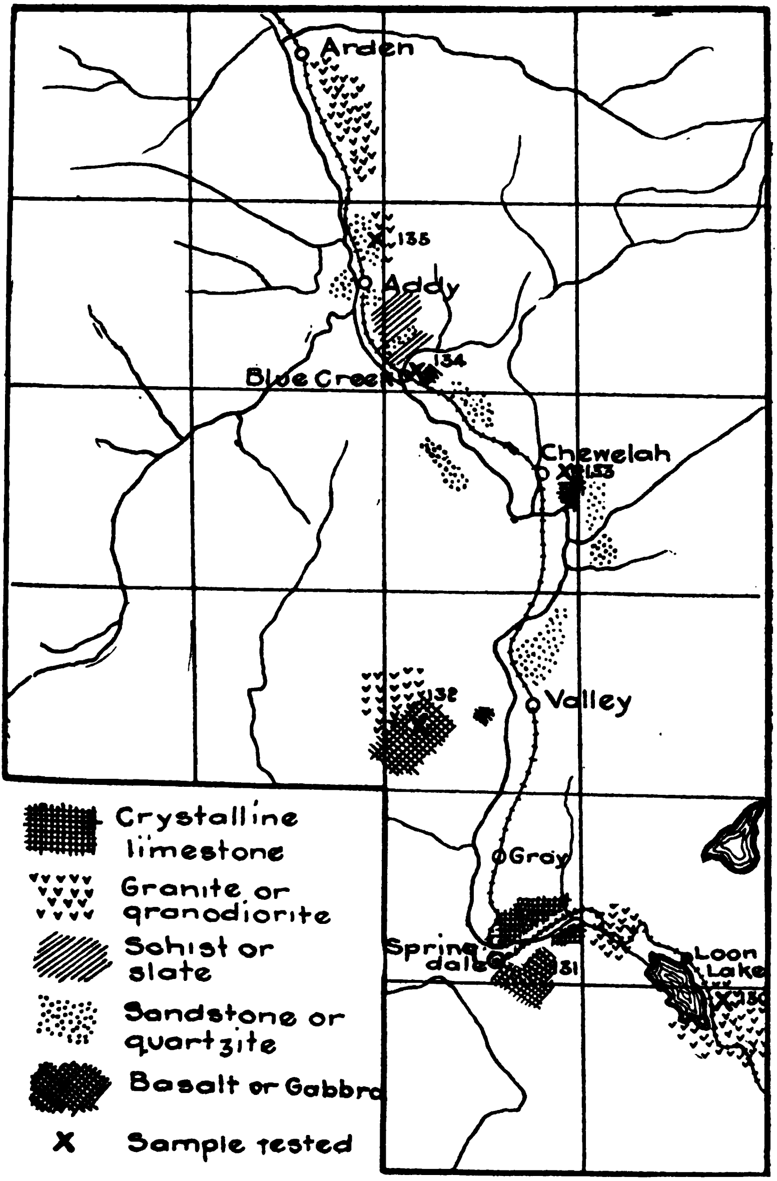
For nearly all the distance from the Spokane river to Highland the Great Northern railway is paralleled on the west by a high ridge of basalt. In some of the bolder cliffs several distinct flows may be recognized. Nearly all of the lava is porous and vesicular. Some of it approaches a true pumice. Only at rare intervals can any be found which could be considered as a possible source of road material. Occasionally there are some basaltic columns where the rock is compact and rather free from steam holes. In all such cases the amount of overburden is too great to use these columnar deposits. At a locality about 2 miles south of Highland there is a 40-foot cliff where the slope of broken rock beneath it reaches to the track. The rock in the cliff and talus slope has a low percentage of steam holes and probably would be serviceable as a source of road material. A sample was secured from the broken rock on the slope. As indicated by the test the rock is a fine grained, dark gray basalt. It is a hard rock with average wearing value and low cementing value. If the rock were carefully selected it should make a satisfactory road material.

STEVENS COUNTY.

GENERAL STATEMENT.

This is a very large county, occupying the northeastern corner of the state. It is marked by great diversity of topography. It has three conspicuous north-south valleys, with a corresponding number of high mountain divides. The Columbia and Pend Oreille rivers flow in deep valleys, usually narrow; the Colville occupies a valley of moderate depth and great width. The highlands are very irregular and broken, and universally forest clad.

There is a great variety of rocks within the county. The mountain spurs or outliers of the Rockies are composed chiefly of quartzite, schist, slate, and crystalline limestone or marble. Intruded into these are great dikes of igneous rocks, such as basalt and andesite. The great flow of the Columbia basalt overlapped the southern rim of the county to some extent. As a rule rock exposures are numerous and may be found almost everywhere. The basalt affords the best road material and should be used whenever convenient. Some tests were made on the crystallized limestones or marbles which are very widespread in occurrence. As a rule this variety of rock is rather soft to use as a road material, although its cementing value is high. On the other hand the granites and granodiorites are very hard but their cementing power is weak. Beds of granite occur abundantly along the sides of all the valleys and may be utilized in surfacing the less travelled roads.



STEVENS COUNTY: Along the Colville valley from Loon Lake to Arden.

Scale, 1 inch equals 6 miles.

The chief towns of the county are located in a linear arrangement within the large valleys. Trunk lines of highways will soon be a necessity to connect these towns in a chain-like fashion. The agricultural industries are rapidly increasing in importance in the valleys and the rural population growing. Road building will soon needs be undertaken on a large scale. The county is fortunate in having road materials so conveniently spaced that the length of haul will usually not be great.

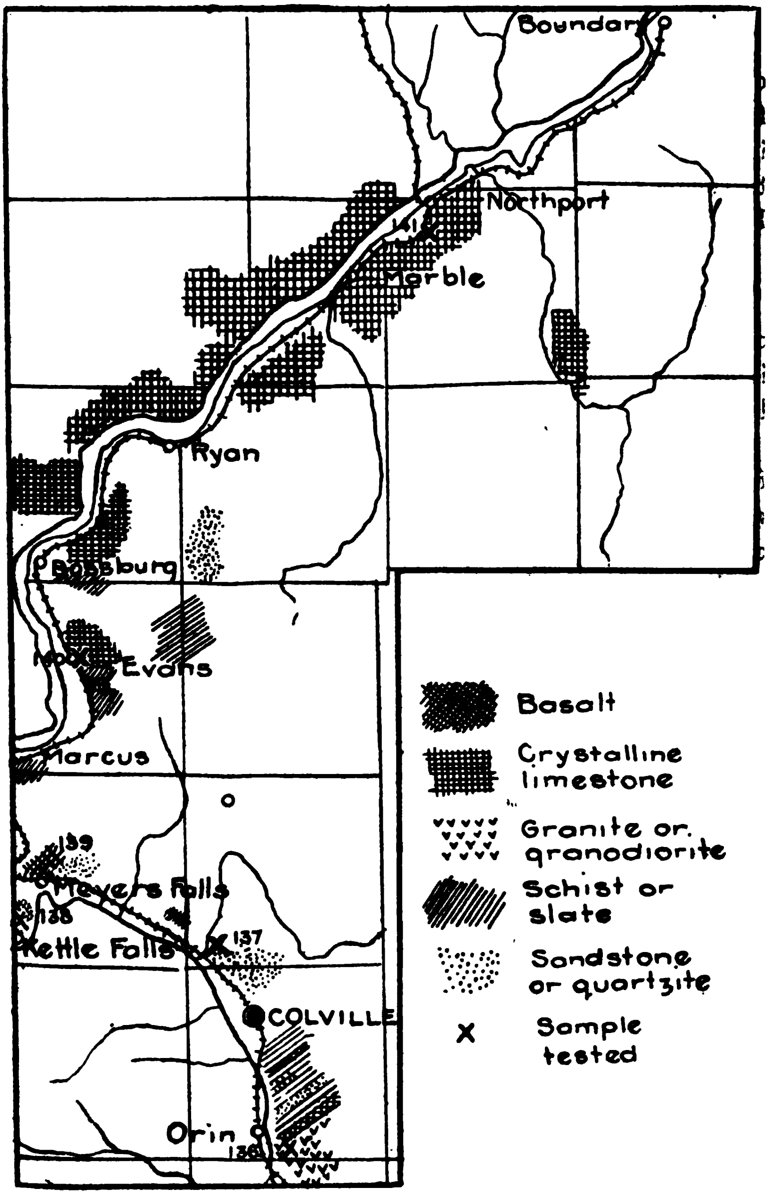
ROAD MATERIALS TESTED.

Serial Number 130.

At the south end of Loon Lake there are some small hills of granodiorite. The rock is exposed in railway cuts from 5 to 30 feet in depth, and in ledges to the northeast of the railway. All the rock is much weathered near the surface. A sample was taken about 50 feet above the railway, on the east side of the track. As demonstrated by the test it is a very coarse grained, light gray rock, intermediate in composition between a granite and a diorite and hence called a granodiorite. It is a hard rock with low toughness, average resistance to wear and fair cementing value. It can not be recommended as a material for straight macadam construction other than in the foundation course.

Serial Number 131.

This sample was secured from the broken rock at the foot of a basalt bluff about 200 yards east of the station at Springdale. The bluff is 200 feet or more in height with a long slope of broken rock which extends down to the railway track. The broken blocks range in size from 1 inch to 3 feet in diameter, and appear on the surface just as fresh and unaltered as rock from within the ledge. The amount of rock available is very large and it is a very convenient location for a quarry. The rock is a fine grained, dark gray basalt, which breaks with a shell-like fracture and has a clinking sound when struck with a hammer. In the rock there are a few tiny steam holes. The rock is hard and tough with high resistance to wear and low cementing value. It should make a satisfactory road material.



STEVENS COUNTY: Along the Columbia and lower Colville valleys.

Scale, 1 inch equals 6 miles.

A little way northeast of Springdale there are large deposits of crystalline limestone. This was once an important center for lime burning. The limestone runs so high in magnesia that it is no longer burned for quicklime. The rock is fine grained to compact and varies in color from white to very dark gray. No sample was taken for testing.

Serial Number 132.

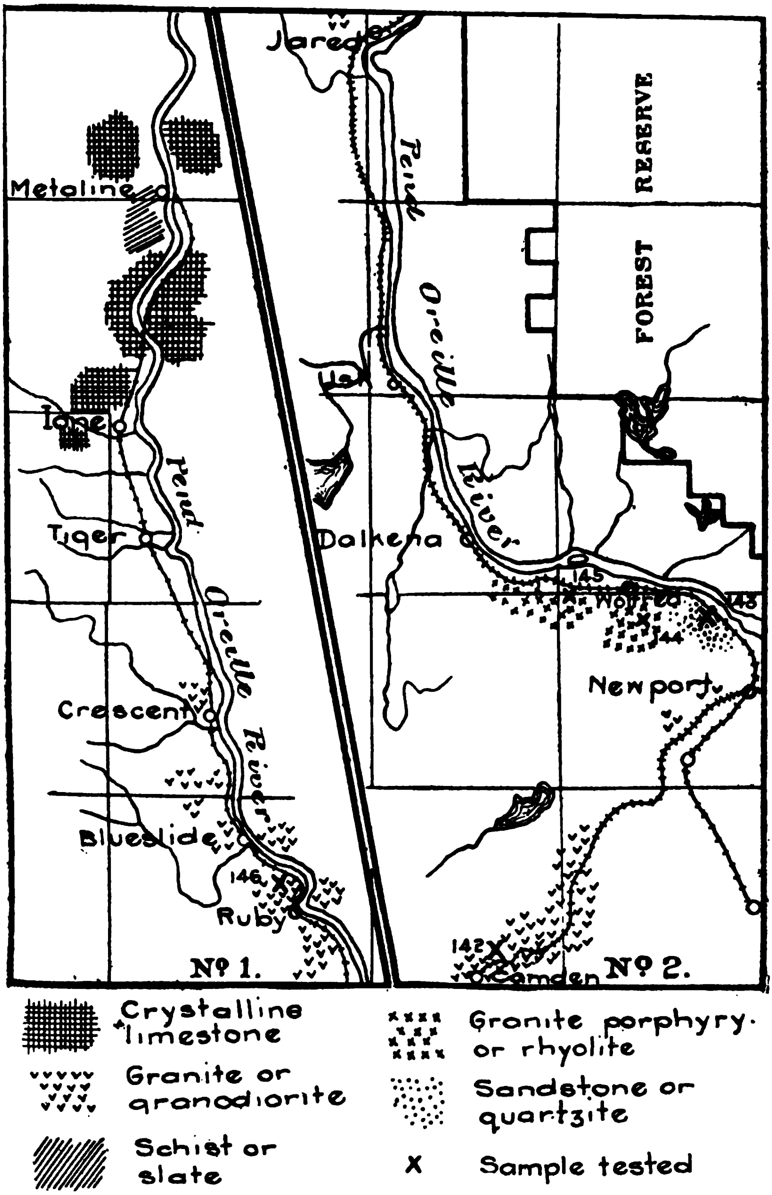
This specimen was taken from a basalt ridge 4½ miles west of Valley and 1¼ miles southwest of Wait's lake. The ridge is one-fourth of a mile southeast of the county road and has a length of several thousand feet. At the top of the ridge there is a perpendicular face of rock varying in height from 10 to 40 feet, with a steep slope of broken rock from 200 to 400 feet in width. There are some tiny steam holes but very few large ones. According to the test the rock is a fine grained, dark steel gray, porous basalt. It has average hardness, is a little low in toughness, rather high resistance to wear, and very low cementing value. It should make a satisfactory road material.

Serial Number 133.

East of Chewelah, in the W½ of Sec. 18, T. 32 N., R. 41 E., there is a ridge of marble from 50 to 100 feet in height. On the ranch of John Schoenberg, where the ridge is nearly 100 feet high, some of the rock was quarried years ago and burned for quick lime. The beds strike north and south, and dip westward at an angle of 44 degrees. The layers vary in thickness from 8 to 18 inches, and vary in color from white to dark gray. A sample was secured at the old quarry. According to the test the rock is a dolomitic marble of average hardness and resistance to wear, low toughness and good cementing value. If used on highways it would be best suited for roads with a light traffic.

Serial Number 134.

Immediately east of the railway at Blue Creek there is a rocky hill about 150 feet high. It consists principally of a greenish, fine grained rock, some of which is slightly schistose. Outcrops occur at intervals from the base to the top of the hill. The



STEVENS COUNTY: No. 1—Part of the lower Pend Oreille valley.
No. 2—Part of the upper Pend Oreille valley.

Scale, 1 inch equals 6 miles.

amount of overburden is small. A sample was secured from a ledge about 30 feet above the railway track. As determined in the laboratory the rock is a highly altered gabbro. It is a hard rock with average toughness, high resistance to wear and fair cementing value. It should make a satisfactory material for macadamizing highways.

Serial Number 135.

This sample was taken from the broken blocks at the foot of a long cliff 2 miles north of Addy. According to the test made upon it the rock is an altered granite porphyry. It is a hard rock, with average toughness and resistance to wear, and good cementing value. It is recomended only for the foundation course in plain macadam construction.

Serial Number 136.

One mile southeast of Orin there is a ridge of granite with cliffs from 50 to 100 feet in height. The cliffs are always bordered by large talus slopes. They are not over one-fourth of a mile from the railway track, with level ground between. A sample was secured from the foot of a cliff near the limestone contact. As determined by the test the rock is a coarse grained, light gray granite. It is a hard rock, with low toughness and resistance to wear and fair cementing value. It is not recommended as a road material except in the foundation course.

Serial Number 137.

Northwest of Colville 2½ miles, and northeast of the railway, there is a hill several hundred feet high, with a long talus slope reaching almost to the county road. The hill is partly wooded but the overburden is light over much of the slope. A sample was taken from the northwest corner of the hill. It is a sandstone, with much iron. Not enough material was sent to the laboratory for all the tests to be made. The fresh rock is a dull bluish gray color, fine grained, with medium hardness and toughness. It possesses fair cementing value and it is believed could be used satisfactorily in road building. It should not be used in macadamizing because better materials are not far away.

Serial Number 138.

This sample was secured from a small hill one mile northeast of Kettle Falls in Sec. 24, T. 36 N., R. 38 E. On the hillside there is a cliff 50 feet high and several hundred feet long, with a large talus slope below. According to the test made upon the rock it is a medium grained, greenish gray, highly-decomposed diabase. It has average hardness, rather high resistance to wear, low toughness and good cementing value. It possesses the requisite qualities for a good road material.

This rock has been used in surfacing a part of the highway from Kettle Falls to Meyers Falls. The rock was not run through a crusher, but the smaller fragments of broken rock at the foot of the cliff were used in their natural condition. The roadway was not crowned and the broken rock was packed down only by use. The rock was hauled over a private road one-half mile until the county road was reached.

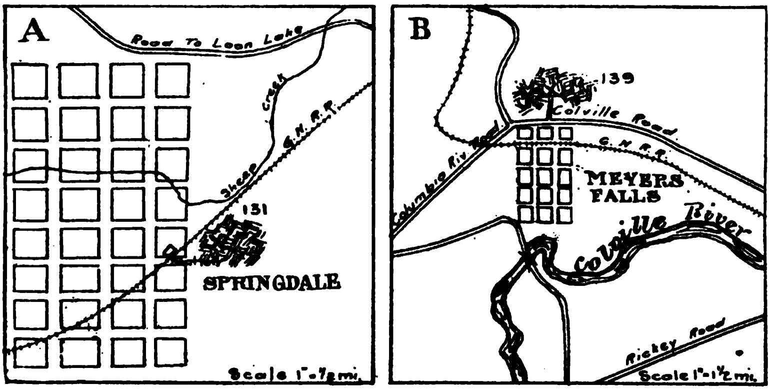


FIG. 42. A—Ledge of basalt at Springdale. B—Deposit of volcanic ash at Meyers Falls.

Serial Number 139.

About 1,000 feet north, and a little east, of the railway station at Meyers Falls is the foot of a bluff 700 feet high and one-fourth of a mile long. On the south face of the bluff numerous ledges of rock crop out. Near the foot of the bluff there are some exposures of rock from 10 to 25 feet in height with a long slope of detrital matter at the base. The detrital material consists of fragments of rock averaging an inch or two in diameter, mixed with a reddish clayey soil. This broken rock has been used in its natural condition with fair success on the main street of Meyers Falls. Only a thin veneer of the rock was applied and it was left to be packed down by traffic. A sample was taken from the fresher rock for a laboratory test. It proved to be a fine grained, greenish gray, highly indurated volcanic ash. It is a tough rock with average hardness, rather high resistance to wear and fair cementing value. If properly prepared it should make a satisfactory material for road construction.

Serial Number 140.

At Evans the Idaho Lime Company operates a lime-burning plant consisting of three kilns, with a capacity of 100 barrels for each 24 hours. A quarry face has been developed 200 feet long and from 6 to 25 feet in height. The overburden of soil is slight. The rock is a compact, crystalline limestone, or marble. A sample was selected from the quarry. According to the test it is a rather soft rock with low resistance to wear and fair cementing value. As a road material it would be suitable only for roads having a very light traffic.

Serial Number 141.

From Northport down the Columbia river as far as Bossburg, the valley is bordered on both sides for much of the distance by bluffs of crystalline limestone or marble, varying from 500 to 1,200 feet in height. At Hudson, 2½ miles southwest of Northport, there is a quarry where marble has been taken out for use as a flux at the Northport smelter. The face of rock in the quarry is about 250 feet long and from 50 to 100 feet in height. A short spur track connects the main line with the quarry. According to the test made upon it the marble is a rather soft rock with low toughness, average resistance to wear, and fair cementing value. It would not be wise to use this marble as a road material except on highways subjected to very light traffic.

Serial Number 142

One mile northeast of Camden, a few hundred feet west of the railway track, there is a hill of granitic rock several hundred feet high. A cliff of rock 50 feet high is exposed near the base of the hill. A sample was taken from the broken blocks at the foot of this cliff. By test the rock is a coarse grained, mottled gray granodiorite. It is a hard rock with low toughness, average resistance to wear and fair cementing value. It is not recommended as a road material except for the foundation course.

Serial Number 143.

Two miles northwest of Newport the railway runs through some rock cuts. The largest cut is 250 feet long and 20 feet deep. The rock is stratified, with a strike of north 18 degrees west and a southwest dip of 40 degrees. A sample was secured at the middle of the largest cut. As proven by the test the rock is a very dense, fine grained, greenish gray, highly indurated sandstone. It is a hard rock, with average resistance to wear and low cementing value. It is not a desirable rock to use in road building.

Serial Number 144.

This sample was taken from a ledge along the highway about 1½ miles south of Wolfred. At this point the rock has been blasted out to make a roadway and fresh samples were secured. As determined by the test the rock is a greenish gray, altered granite porphyry. It is a hard, rather tough rock, with high resistance to wear and fair cementing value. It is best suited for roads having a heavy traffic.

Serial Number 145.

Between Dalkena and Wolfred there is a range or ridge of low hills not over 200 feet high, on the east side of which there are occasional small exposures of weathered rock. A sample was collected near the top of a hill about 2 miles west of Wolfred and 500 feet south of the railway. The hill is about 150 feet high with a 50-foot ledge of rock exposed. As determined by the test the rock is a greenish gray, highly altered rhyolite.

It is a hard rock, with rather high resistance to wear, low toughness and fair cementing value. As a road material it would be best suited for use in the foundation course in macadam construction.

Serial Number 146.

Less than a mile north of Ruby the river makes a bend around a protruding bluff of granite. A sample was taken of the fresh rock in the railway cut at this place. As determined by the test it is a hard rock, with very low toughness, average resistance to wear and fair cementing value. It is not a desirable rock to use in the construction of macadam roads.

THURSTON COUNTY.

GENERAL STATEMENT.

This county is located within the basin of Puget Sound. At the extreme eastern end of the county there are some elevations which represent foothills of the Cascades. Along the western margin of the county there are hills which are outliers of the Olympics. Apart from these highlands the whole county is a lowland, but little above the sea. The shore line is very irregular, being marked by inlets, bays, points and islands.

Outcrops of rock occur very frequently in Thurston county. The chief localities where bed-rock appears at the surface are among the hills of the eastern and western margins and along some of the streams near the southern boundary of the county. The chief kinds of rocks are sandstones and shales on one hand, and intrusions or dikes of basalt on the other. The former occur mainly in the southern part of the county, as at Tenino and Bucoda, where they contain seams of coal. As a rule these rocks are worthless in road building. Outcrops of basalt occur among the hills at the western end of the county, and at least two localities on Puget Sound. In general this rock will produce road materials of excellent quality.

The lowlands of the county consist very largely of plains of gravel of glacial origin. The gravels are so porous that the rainwater is carried away chiefly underground and surface streams are few. Because of the perfect drainage and easy grades good roads are easily made anywhere over the gravel plains. The gravel affords good material for surfacing wherever the traffic is light. Occasionally beds of boulders are found which would yield good crushed rock for macadamizing purposes. The boulders are generally of igneous origin, and are mainly granite, basalt and andesite. There are ample basalt ledges to yield the necessary crushed rock for the main thoroughfares or trunk lines of the county, and the gravel that

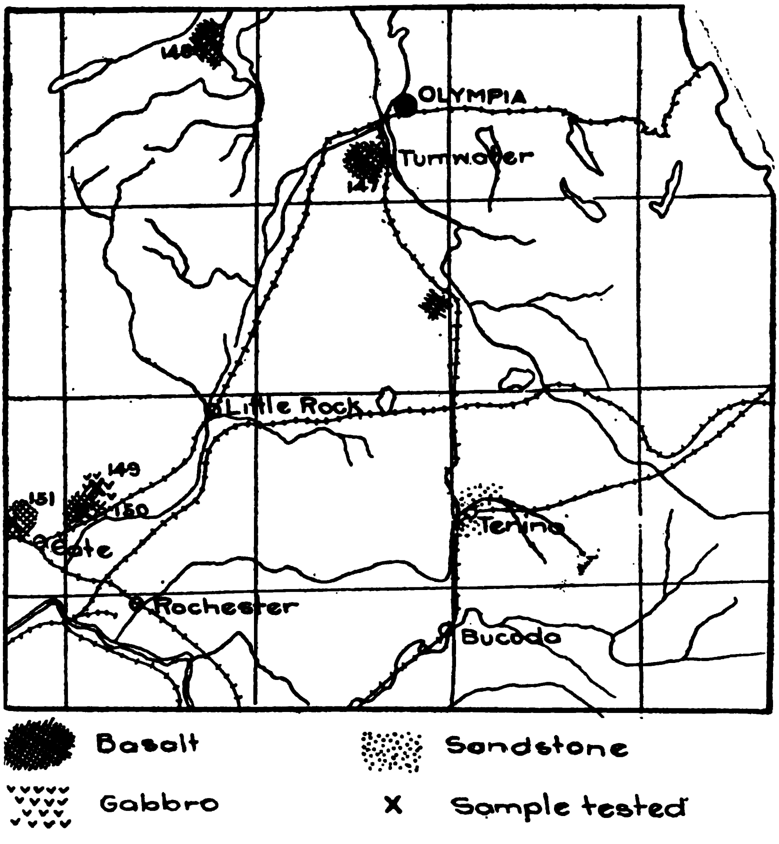


FIG. 43. Western part of Thurston county.
Scale, 1 inch equals 6 miles.

is everywhere so abundant will insure an excellent system of secondary roads.

ROAD MATERIALS TESTED.

Serial Number 147.

South of Olympia, at Tumwater, soft, weathered basalt outcrops at the falls. About a mile southwest of Tumwater, near the top of the hill, there is a small abandoned quarry in which a rock face from 5 to 15 feet high and about 40 feet long is exposed. The basalt of the hill is covered with a thin veneer of soil. The weathered portion of the rock is rather soft. A sample was taken from some of the large blocks in the quarry. As indicated by the laboratory test the rock is a very fine grained, grayish black basalt. It is a hard, rather tough rock with high resistance to wear and good cementing value. It should make a satisfactory material for use in macadam construction.

In Sec. 31, T. 18 N., R. 2 W., there is a hill on which basalt ledges from 2 to 6 feet thick crop out. This locality is about 4 miles southwest of Tumwater, and west of the north end of Black lake. There are some small ledges along the wagon road at the foot of the hill, as well as above. The basalt is soft, dark, fine grained, and much weathered.

In the NE¼ of Sec. 24, T. 17 N., R. 2 W., there is an abandoned quarry on the hillside. It is situated 5 miles southeast of Tumwater and one-fourth mile west of the Port Townsend and Southern railway. In this old basalt quarry there is a face of rock exposed about 75 feet long and 20 feet high. There is an overburden of soil ranging from 2 to 4 feet. The rock is dark gray in color, coarse grained, porous, very soft and yet quite tough.

Serial Number 148.

Near the south end of Eld inlet, or Mud bay, northwest of Olympia, there is a basalt quarry which was in operation for some time. It is located in the SE¼ of Sec. 2, T. 18 N., R. 3 W., and belongs to Swan Solbeck. The quarry is situated on a hillside of moderate slope where there is an overburden of about 3 feet of soil. Enough rock has been removed to give a face 40 feet high in the quarry. The floor of the quarry is about 500 feet from the beach and 150 feet above. The old tramway from the quarry passes above the county road, on its way to the bunkers at the water's edge.

The rock was formerly quarried and scowed to Tacoma where it was used for riprap and in macadam construction. A sample was selected for testing from some of the large blocks in the quarry. The rock is a fresh looking, compact, fine grained, gray basalt. It is a hard rock, with average toughness, high resistance to wear and good cementing value. It should make a very good road material.

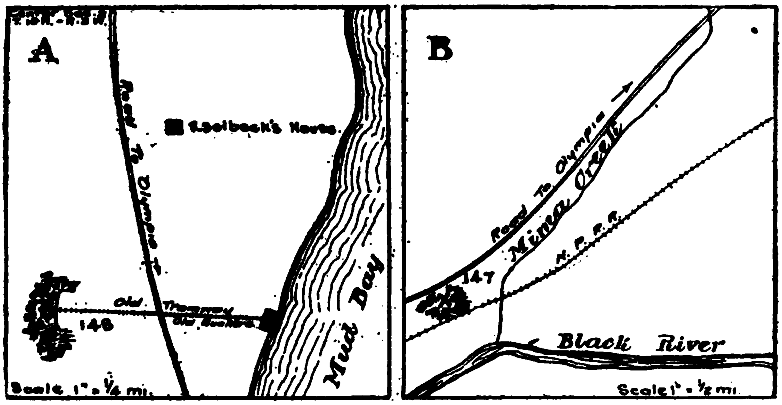


FIG. 44. A—Basalt quarry west of Olympia, on Mud Bay. B—Ledge of rock 3 miles northeast of Gate.

Serial Number 149.

Three miles northeast of Gate, and one-fourth mile west of the county road, in the NW¼ of Sec. 20, T. 16 N., R. 3 W., some small ledges of rock are exposed in a creek bed and gully on the hillside. The outcrop is only 3 feet thick, but the face of rock can be readily increased to 10 feet by a little blasting. According to the test made of this rock it is a dark greenish gray, coarse grained, gabbro. It is a soft rock with low toughness and resistance to wear and good cementing value. As a road material it is suitable for roads only that are subjected to light traffic.

Serial Number 150.

About 2 miles northeast of Gate there is a 15-foot perpendicular ledge of basalt exposed on the west side of the railway track. The overburden consists of a thin layer of soil. The outer portion of the rock is weathered but that within the ledge is fresh looking and compact. According to the test made upon the sample taken from this ledge it is a fine grained, dull greenish black, highly weathered basalt. It is a soft rock, with low toughness, average resistance to wear, and excellent cementing value. Because of its softness and low toughness, it would be suitable only for roads where the traffic was light.

Serial Number 151.

One and one-half miles west of Gate, near the county line, there is a basalt quarry on the north side of the railway track. It has been operated by the Northern Pacific Railway company for the purpose of securing rock for riprap. In the quarry a face of rock has been developed 100 feet long and 25 feet high. The height can not be readily increased because there is only a gentle rise to the ground back of the quarry. The rock is so fractured and broken that only small blocks can be secured. A sample of the fresh rock was taken to be tested. It proved to be a gray black, very fine grained basalt. It is a soft rock with low toughness, average resistance to wear, and excellent cementing value. It should make a satisfactory material for roads subjected to light traffic.

WAHKIAKUM COUNTY.

GENERAL STATEMENT.

This is one of the smallest counties in the state. It has an east and west length along Columbia river of 25 miles, and extends north from that stream for a maximum distance of 16 miles. The surface is very hilly and irregular, the lowlands being confined to narrow belts along the main river and its tributaries. The rainfall is heavy so that the whole county was once forest clad.

The rock outcrops along Columbia river are chiefly basalt. The basalt has come into place as surface flows of molten rock rather than as dikes. Very much of the rock is too full of steam holes and other pores to be serviceable. There are many localities where the rock is so dense and compact that it will

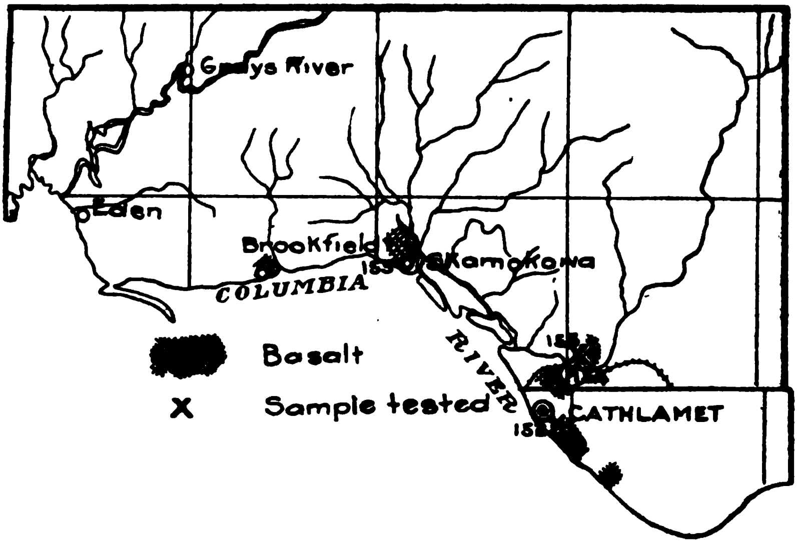


FIG. 45. Map of Wahkiakum county.
Scale, 1 inch equals 6 miles.

yield excellent material for macadamizing purposes. There are several places along the river bank where the cliffs of basalt are in such a position that the transportation problem is simple and the rock may be shipped with the greatest ease.

The people of the county live mainly along Columbia and Grays rivers. The principal method of travel has always been by water. There are not many miles of public roads because only a few people live away from navigable water; as the forests of the alluvial and fertile valleys give way to farms the matter of good roads will be a serious one. When the necessity arises for first-class highways the abundance of basalt will make it possible for crushed rock to be delivered anywhere in the county by a short haul and at a minimum cost.

ROAD MATERIALS TESTED.

Serial Number 152.

There is much basalt around Cathlamet, not only in the town but along Columbia river to the southeast, and in some of the hills to the northeast. Southeast of the town perpendicular basalt cliffs rise from the edge of the water. A sample was secured from the base of a cliff, one-third of a mile up the river from the Cathlamet wharf. At this point the cliff is 100 feet or more in height and has an overburden of several feet of soil. A scow can be readily brought to the foot of the cliff, so that transportation by water would be simple. The rock contains a small percentage of tiny steam holes. According to the test made of this rock it is a fine grained, dark gray basalt. It is a hard rock, with low toughness, average resistance to wear, and fair cementing value. It should make a satisfactory material for macadamized highways.

Serial Number 153.

Three and one-fourth miles northeast of Cathlamet there is a small quarry by the roadside, owned by the county, which was opened in 1908. It is situated in the SE ¼ of Sec. 31, T. 9 N., R. 5 W. A face of rock has been developed which is over 100 feet long and from 15 to 25 feet in height. There is a slight overburden of soil. The hill has such gentle slopes that the face of the rock can scarcely be increased in height. Steam holes are present, and the rock varies much from place to place in the number of cavities. The steam holes vary in size from that of a pinhead to an almond. A sample of the fresh rock was secured for testing. The result showed the rock to be a very porous, fine grained, grayish black basalt. It is a rather hard rock, with low toughness, high resistance to wear, and good cementing value. It should make a satisfactory material for highway construction.

The rock crushing plant at the quarry consists of a portable steam engine, crusher, and steam drills. Several miles of the adjacent highway have been surfaced with rock from this quarry, and the roads are in good condition.

Serial Number 154.

About 1,000 feet west of the county quarry above described, near the intersection of the county road and the Bradley Logging Company's railway, there is a perpendicular basalt cliff. It varies from 25 to 50 feet in height, and extends for 300 feet or more along the railway track. In constructing the railway much rock was blasted out, thus giving fresh exposures. Back of the edge of the cliff there is a steep slope, with a veneer of soil. The amount of basalt here is greater than in the county quarry noted above. A sample was taken of some of the fresh material and tested in the laboratory. The basalt is dense, fine grained and gray black in color. It is a hard, tough rock, with high resistance to wear and fair cementing value. In macadam construction it could be used with success.

Serial Number 155.

There are some large exposures of basalt in the vicinity of Skamokawa, especially north of town. In the north part of the village, on the west side of the river, in the SW¼ of Sec. 8, T. 9 N., R. 6 W., there is a steep hill several hundred feet high. One end of the hill has been cut off, giving a face of rock about 75 feet high. The county quarries the rock here and prepares it for road use. A crusher and engine were placed in operation in June, 1909. The crushed rock has been used in surfacing several miles of highway around Skamokawa. A sample was taken of some of the rock that was ready for the crusher. According to the test made upon it the rock is a fine grained, grayish black, porous basalt. It is a hard,

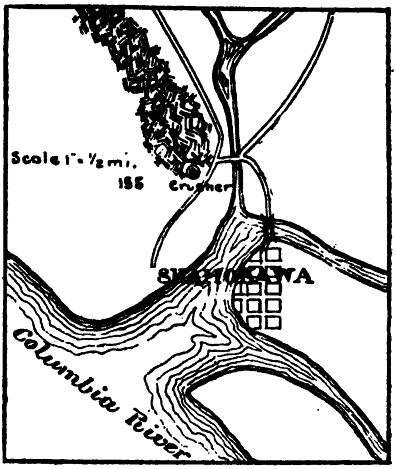


FIG. 46. Basalt ledges near Skamokawa.

tough rock, with high resistance to wear and fair cementing value. It possesses the qualities of a satisfactory road material.

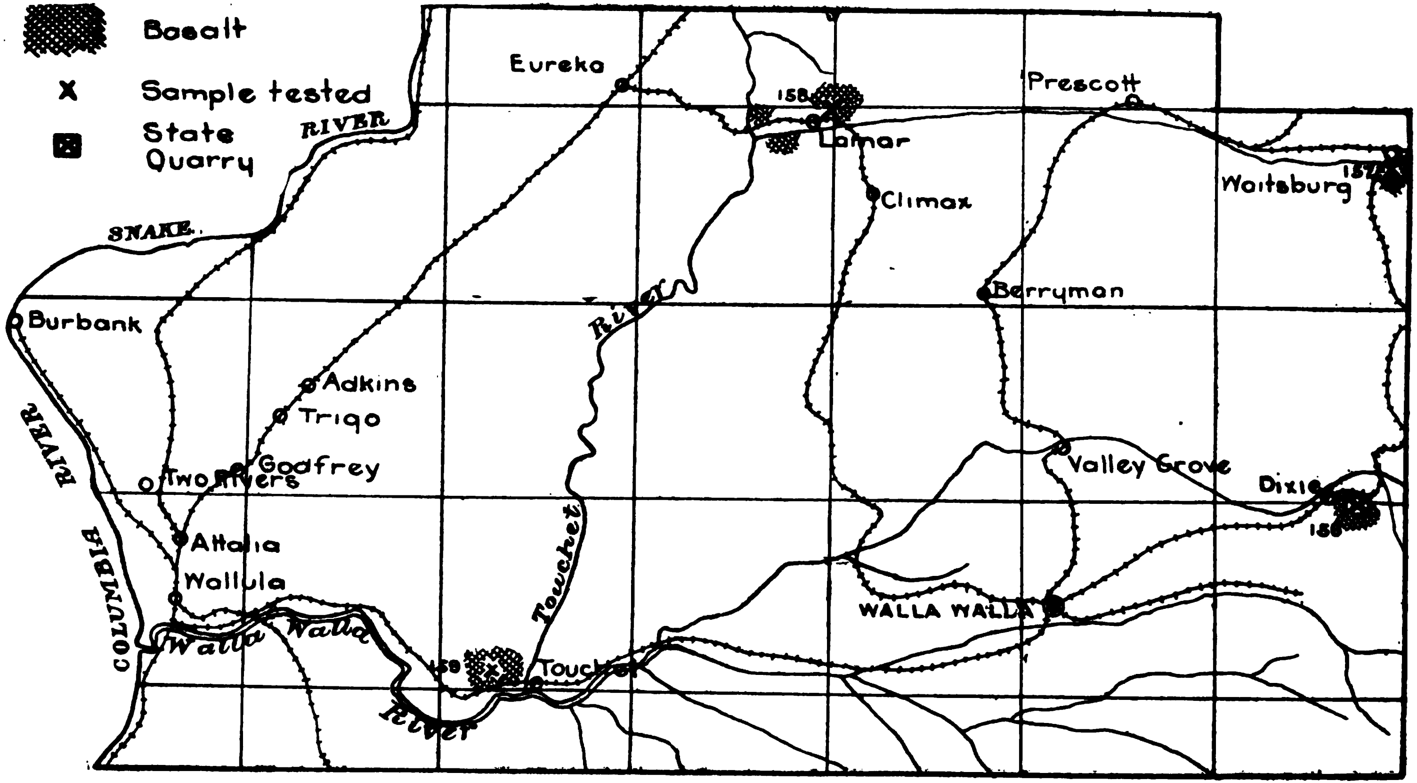
For several hundred feet north from the quarry the wagon road follows the foot of the perpendicular cliff forming the east face of the hill above described. The cliff is 150 feet or more in height and it presents some excellent examples of columnar jointing. The rock is compact and hard, and is far better exposed and appears more uniform in quality than at the county quarry.

WALLA WALLA COUNTY.

GENERAL STATEMENT.

This county has the Columbia and Snake rivers for its western and northern boundaries, and Oregon for its southern one. In topography it has a mixture of plain, plateau, and mountain. Along Columbia river there is a low plain, from 300 to 400 feet above sea level. Going eastward, this plain merges into a plateau which comprises by far the largest part of the county. The Blue mountains send their spurs for a little way across the eastern margin of the county. The plateau has a variable surface, sometimes very gently rolling, and at other times trenched by prominent canyons. The interstream areas often show that their surface slopes have been given their outlines by the action of the winds. The fine soil has been so wafted about by the prevailing winds that the hills have been shaped by that agency.

Outcrops of rock are not abundant in the county because of the heavy mantle of soil. The chief places where they may be found are along the walls of the valleys, chiefly the canyons. In the northwestern part of the county there are occasional occurrences of sandstones and shales, such as may be seen in some of the cuts along the Northern Pacific railway. Similar rock occurs in the vicinty of Walla Walla where artesian water is obtained from it. Over the major portion of the county basalt is the underlying bed-rock. It makes conspicuous outcrops along the canyon walls of Snake river; it forms low cliffs along the Walla Walla and Touchet rivers, and their larger



Scale, 1 inch equals 6 miles.

SOUTHWESTERN PART OF WALLA WALLA COUNTY.

tributaries; it is occasionally encountered in the railway cuts. Very frequently it contains so many cavities that it is of doubtful value as a road material. If it be carefully selected so that it is dense and compact it affords excellent material for macadam construction.

The highway materials are almost wholly limited to those derived from bed-rock. There has been no glaciation within the confines of the county and hence all gravel is of stream origin. Gravel occurs more or less abundantly in the bars and benches of the larger streams. It is usually quite inaccessible for road use and hence will never be utilized to any large extent.

This is preeminently an agricultural county, with the growing of wheat and fruit as the chief industries. In the lowlands of the western margin irrigation is necessary for success in agriculture. In time there will be only a very small fraction of the county that is not under the plow. The construction of good roads on a large scale will soon be a necessity. The roads that are surfaced with dirt are always very dusty in summer and muddy in the winter and spring. The time is at hand when the main lines of highways should be macadamized and placed in a first-class condition. There is an abundance of basalt conveniently located for transportation to construct all the permanent roads that will ever be needed.

ROAD MATERIALS TESTED.

Serial Number 156.

This sample was taken from the state quarry at Dixie, which is 11 miles east of Walla Walla, on the branch line of the Northern Pacific railway which extends to Dayton. The quarry is located one-half mile southeast of Dixie. It is alongside the railway, with its floor 4 feet above the level of the track. The quarry has been opened at the foot of a hill which has a slope of about 35 degrees and an extreme height of 300 feet. The overburden of soil and broken rock varies from 1 to 3 feet. The steeper slopes about the hillsides are grass-covered while the gentler ones of the hilltop are cultivated.

The length of the quarry face is 320 feet, with a maximum vertical height of 60 feet. The rock is a fine grained basalt, dark in color, and has the usual conchoidal fracture with sharp edges. The base of the ledge, from the floor of the quarry to a height of 30 feet, is very good rock. It is compact, hard, and free from steam holes. In the upper 30 feet of the quarry face the rock is more or less porous, containing steam holes and other cavities. According to the test made upon the rock from the base of the quarry face it has average hardness, low toughness, rather high resistance to wear, and fair cementing value. As crushed rock for macadam construction it should be satisfactory material.

This quarry was opened some years ago and extensive shipments have been made to Walla Walla where it has been used in macadamizing the streets. It has lately been transferred to the state, but a crushing plant has not yet been put in operation.

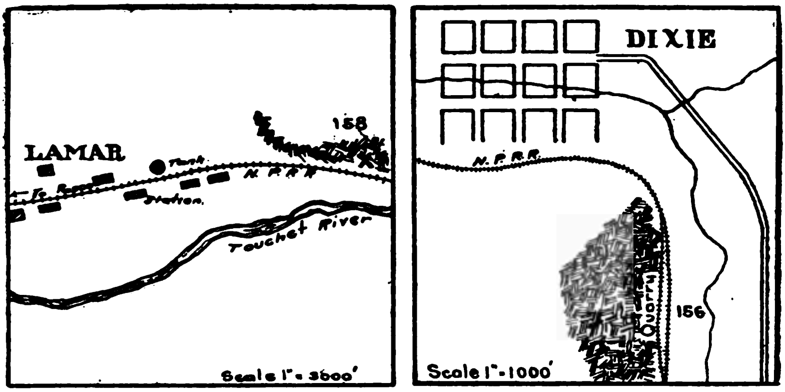


FIG. 47. A—Outcrops of basalt in the vicinity of Lamar. B—State quarry at Dixie.

Serial Number 157.

On the south wall of the valley at Waitsburg there are many outcrops of basalt. The overburden of soil is slight so that the character of the rock may be easily determined. The low cliffs near the base of the hill are made up of compact basalt, very free from steam holes. The ledges above have so much porous rock in them that they are of very doubtful value as a source of road material. A sample was taken of the basalt from the foot of the high bluff, a little above the edge of the river. According to the test the rock is a fine grained basalt; hard and tough, with high resistance to wear and low cementing value. If care is taken in selecting the rock which is free from steam holes, the material from this place may be used successfully in road building.

Serial Number 158.

Immediately east of Lamar, and on the north side of Touchet river, a basalt hill rises for 200 feet above the railway grade. The hill is moderately steep, especially for a distance of 60 feet or so above its base, and has only a scant covering of soil. The railway has made 4 cuts through projecting points of the hill, in a distance of three-fourths of a mile. The rock is uniform in character and free from the quite porous variety and other worthless kinds. An excellent situation is afforded here for a quarry site. A sample of the rock was secured at one of the railway cuts. It is dense, fine grained, gray black basalt; a hard, tough rock with high resistance to wear and fair cementing value. It should make a satisfactory road material.

Serial Number 159.

West of Touchet, along both the county road and the railway, outcrops of basalt are frequent. Very much of it is too porous and full of large cavities to be of any value as a road material. Here and there small areas may be found that would yield enough good material for local use. A sample was secured on a bare hillside about 2 miles west of Touchet. The great bulk of the rock is too full of steam holes to be safely used. The sample was taken from a small ledge where the rock was most free from holes. According to the test it is a black, porous, porphyritic basalt. It is a hard rock with low toughness, average resistance to wear, and excellent cementing value. It should make a satisfactory road material.

WHATCOM COUNTY.

GENERAL STATEMENT.

Whatcom county extends from the Gulf of Georgia to the summit of the Cascades. It has a maximum length of over 100 miles and a width of 25 miles. The northwestern part of the county is a lowland from 200 to 400 feet above the sea. The

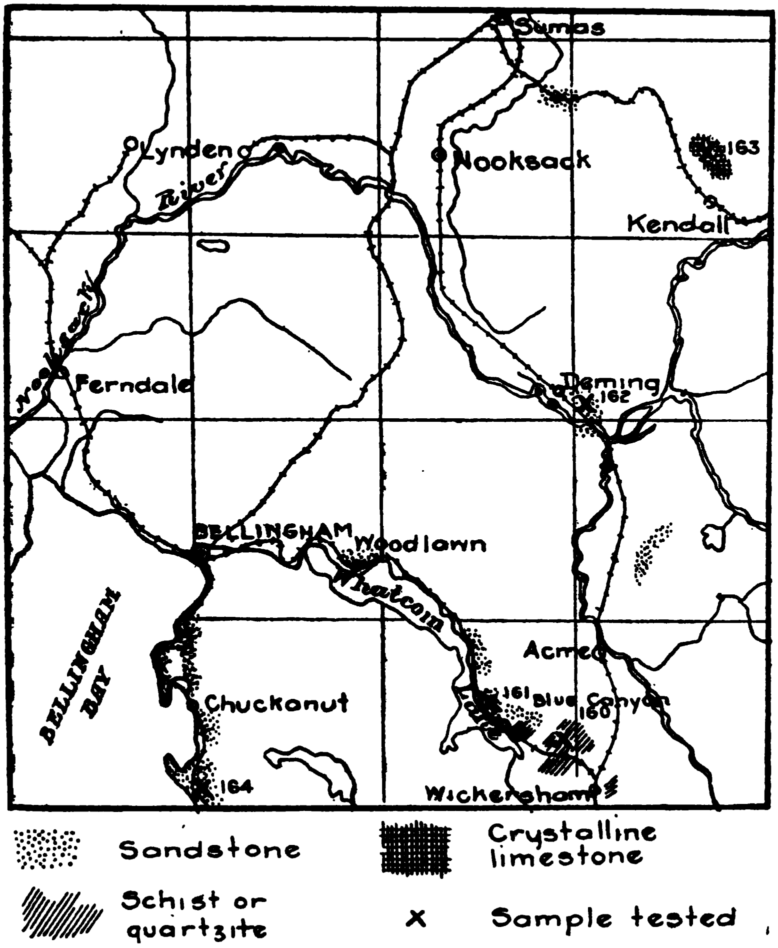


FIG. 48. Western part of Whatcom county.
Scale, 1 inch equals 6 miles.

remainder of the county is largely made up of the foothills and the high mountain masses of the Cascades. The mountains are pierced by some great valleys, such as those of the Nooksack and the Skagit.

Except over the lowlands outcrops of rock are very abundant throughout the county. Very many varieties of rock are found. About Bellingham the common rocks are sandstones and shales. The former in some instances is used as a building stone but it is too soft for use as a road material. South and east of the sedimentary areas above noted the prevailing rocks are schists and slates. These are also too soft and have too little resistance to wear to make serviceable road materials. Crystalline limestones or marbles outcrop in the vicinity of Kendall. Although of inferior hardness they would make fairly good road materials because of their superior cementing power. The rocks of the more inaccessible eastern portion of the county are largely schists and slates, with great areas of igneous rocks, such as andesites and granites. The rocks which are conveniently located for use are generally of inferior value as road materials.

Throughout the western end of the county glacial deposits abound, such as beds of till and layers of gravel. Where these materials have been used in road building they have given fair results. This is particularly true where the roadways have been well drained and where the traffc is light. The till contains enough pebbles to have good wearing qualities and enough clay to cement to good advantage. Both till and gravel make roads with a minimum of dust in the summer and with very little mud in winter.

The lowlands of the county possess a good soil and the forests are rapidly yielding to farms. The rural population is increasing and the road mileage growing. A well ordered system of highways has been laid out to connect the towns one with another, and the farming centers with the towns. The roads in general have been regarded as among the best in the state. Certain trunk lines are now under construction and being planned that will require surfacing with crushed rock because of the heavy traffic. It is probable that material for this purpose will needs be secured without the county. One of the nearest localities beyond the county boundaries is the state quarry at Fidalgo. There are other localities among the San Juan islands.

ROAD MATERIALS TESTED.

Serial Number 160.

This sample was taken from a ledge along the railway track about 2 miles northwest of Wickersham. The rock is a light gray schist which outcrops at many places between Wickersham and Blue Canyon. It is a very soft rock and easily splits up into thin layers. In some places it closely resembles talc. The test made upon it proves that the rock has very low resistance to wear and low cementing value. It would be of no value in the construction of macadam roads.

Serial Number 161.

Near Blue Canyon the rock is mainly coarse sandstone in which there are seams of coal. The rock occurs as high bluffs along the east shore of Lake Whatcom. The railway skirting the lake has made many cuts in the sandstone. A sample was secured from a cut about 5 miles northwest of Wickersham. As determined by the test it is a light yellowish gray, medium grained, loosely textured sandstone. It is a very soft rock with low toughness, very low resistance to wear, and very good cementing value. It is not recommended as a road material.

Serial Number 162.

A little way southeast of Deming there are ledges of sandstone exposed along the county road and the railway. One of the ledges consists of a bare knoll of rock 50 feet high, with a low cliff on one side about 150 feet long. Much of the sandstone is very coarse, and layers of conglomerate and beds of shale are associated with it. A sample was collected from a small knoll adjoinig the roadway. According to the test it is a medium grained, loose textured, yellowish gray sandstone. It is low in hardness, toughness, and resistance to wear. It possesses excellent cementing value. It could not be used satisfactorily as a road material, and is not recommended.

Serial Number 163.

North of Kendall there is a mountain several feet high, with a steep southwest slope. The more gentle slopes of the mountain are wooded, but there are many bare places where the rock outcrops as low cliffs. The base of the hill is mostly schist and slate, while the principal rock on top is crystalline limestone, or marble. Near the north end of the mountain, on the west side, the limestone appears as bold white cliffs which are readily seen from the railway, 2 miles or so away. A sample was taken from this locality for testing. According to the laboratory returns the marble is a rather soft rock with low toughness, average resistance to wear, and fair cementing value. If used as a road material it would be best suited for highways subjected to light traffic. A spur track connects the marble above described with the main line of the Bellingham Bay and British Columbia railway.

Serial Number 164.

For some miles southward from Bellingham sandstone is exposed at intervals along the Great Northern railway and along the beach. The rock is quarried at Chuckanut and used as a building stone. Just north of the Skagit county line, and three miles south of Chuckanut, there is a railway cut in sandstone which has a length of 1,000 feet. On the east side of the track the face of rock reaches a maximum height of 40 feet. The sandstone varies in texture from very coarse to very fine, and is interbedded with shales. A sample was selected from the freshest rock which could be found near the south end of the cut. As determined by the test it is a fine grained, light gray, loosely textured sandstone. It is very soft, low in toughness, and low in resistance to wear. Although it has fair cementing value it is not recommended as a road material.

WHITMAN COUNTY.

GENERAL STATEMENT.

This county is roughly rectangular in outline, with a maximum length and width each of about 57 miles. In general its surface it that of a plateau, with an average height of 2,500 feet above sea level. The plateau has been deeply cleft by Snake river which has incised a canyon over 2,000 feet in depth. Smaller canyons have been made by Palouse river and the lesser streams. Rising above the plateau, often for several hundred feet, there are a few elevations which represent western outliers of the Rocky mountains. Chief among these are Steptoe butte, Kamiak mountain, and Bald butte. The surface of the plateau is a rolling one which has been fashioned partly by the work of the winds and partly by running water. The soil is very fine grained and at a more arid time in the past was rather freely blown about by the winds. The outlines of the hills show the influence of the prevailing winds, the steeper slope being on the leeward side, and the more gentle slope on the windward side of a hill.

The bed-rock of the county is almost wholly basalt. The deeper canyons, such as that of the Snake, have pierced the overlying basalt in a very few instances and have uncovered the rock beneath, generally granite. The mountains and buttes above mentioned are generally composed of quartzite, schist, and related metamorphic rocks. The flows of lava lapped about them but they have never been covered by the basalt.

The outcrops of basalt are seen to best advantage along the canyon walls. They are also of frequent occurrence as the rim-rock borders of the smaller valleys. Along the railways are cuts through the basalt ledges. Much of the rock is very porous and not of sufficient firmness to be recommended as road material. Deposits of compact and dense rock are of widespread occurrence and no locality wishing to find basalt of good quality for road use will need to seek very far. Beds of gravel are rare and are mainly limited to the bars and benches along the larger streams.

The great industry of this county is wheat growing. Th farms are large and the rural population comparatively sma It is not likely that any of the roads will soon be macadamiz except those of the largest importance which connect the town As a rule all the roads are muddy in the spring and very dust in the summer and autumn. Whenever the surfacing of t trunk roads is undertaken ample amounts of good crushed roc will easily be secured.

ROAD MATERIALS TESTED.

Serial Number 165.

This sample was taken from Hughes' quarry, located on th hillside immediately south of the business portion of Colfa The rock from this quarry has been much used as a buildin stone in Colfax, Moscow, and in other towns. It has also bee used as paving blocks, in retaining walls, for foundations, etc The rock is a very dense, fine grained basalt, breaking with shell-like fracture and sharp edges. The floor of the quarry i 60 feet above the level of the nearby county road. The floo area of the quarry is about 200 feet by 150 feet. The quarr face is 20 feet high, with an overburden of 10 feet of broke rock. As determined by the test the rock is very hard an tough, with high resistance to wear and fair cementing value It should make a good road material for roads subjected t very heavy traffic. A crusher has been installed and is in place although very little crushed rock has been produced thus far.

Basalt of good quality occurs along the electric railway for several miles north of Colfax. About four miles from the town there are some cliffs of basalt that are well located for the establishment of quarries. The quality of rock is good and the quantity practically unlimited.

Serial Number 166.

One mile southeast of Pullman, on the road to Moscow, there is a small basalt quarry on the hillside. It is located near the point where the two railway lines diverge on their way to Moscow. The quarry has a face of 15 feet which will constantly

increase in height as more rock is removed. There is no overburden save a thin covering of soil. The rock is black in color, and fine-grained in texture. It is hard and tough, and the columnar jointing is common. A sample was taken of the fresh rock from the quarry. As proven by the test it has rather high resistance to wear and fair cementing value. It has the qualities of a satisfactory road material. Some of the rock has been crushed and used in surfacing the highway between the quarry and Pullman.

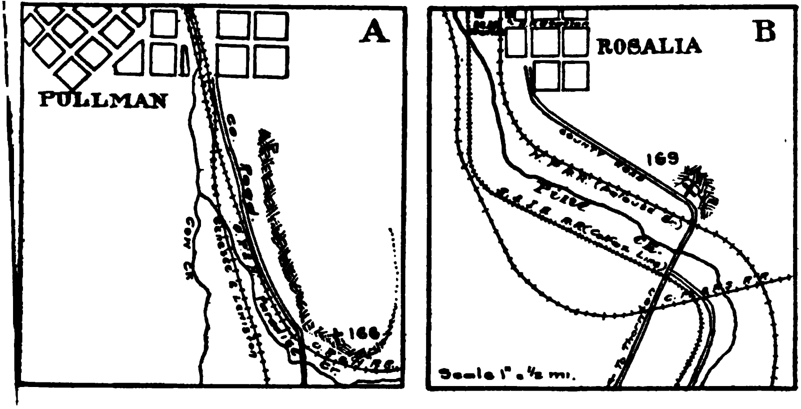


FIG. 49. A—Basalt quarry near Pullman. B—Outcrops of basalt at Rosalia.

Serial Number 167.

There are numerous low cliffs about Palouse composed of excellent rock. Immediately west of the Northern Pacific railway station, on the south side of the river, there is a cliff of good basalt which has no overburden of soil. The cliff varies from 125 feet to 150 feet in height, and has a length of 400 feet. A flat strip of land 300 feet wide separates the cliff and railway. There is another cliff one-half mile east of town on the electric railway line. The face of rock which could be developed there in quarrying would not be more than 40 feet in height but the rock is of good quality. A sample was secured from this cliff. As proven by the test it is a dense, fine grained, gray black basalt. It is a hard, tough rock, with high resistance to wear and good cementing value. For macadam work it should make good material.

Serial Number 168.

This specimen was taken from one of the outcrops on Steptoe butte. As far as can be determined the entire hill is composed of quartzite. The rock breaks readily into blocks which might possibly find a use in street paving. Opportunities for the opening of quarries are good because of the steepness of the slope and scanty soil covering. Transportation may be afforded by the electric railway line which runs near the western foot of the hill. As determined by the test of the sample selected it is a medium grained, light gray quartzite. It is a hard rock with low toughness and resistance to wear, and low cementing value. It can not be recommended for macadam road construction.

Serial Number 169.

This sample was taken from a quarry located less than a mile southeast of Rosalia, on the county road. The floor of the quarry is about 100 feet long by 40 feet in depth. The face of rock has a height of 20 feet with an overburden of 6 feet of broken rock and 1½ feet of soil. The hill in which the quarry is located is flat-topped so that the height of the quarry face will not increase. The rock is a porous lava, fine grained, and steel gray in color. As determined by the test made upon it, it is a hard and tough rock with high resistance to wear and fair cementing value. It has in it the qualities of a satisfactory road material.

The quarry at Rosalia is owned by the county and a rock crusher has been operated there for some time. The crushed rock has been used on the highways and on the streets of Rosalia with very good results.

Serial Number 170.

Along the south bank of the Palouse river at Winona there are basalt cliffs fully 80 feet in height. They extend lengthwise for some distance and afford excellent sites for quarries and crushing plants. A sample was taken from the cliff almost directly south of the town. As determined by the test the rock is a black, porphyritic basalt. It is a very hard and tough rock, with high resistance to wear and good cementing value. Crushed rock from this cliff should make an excellent road material.

A sample was taken from a small quarry at Tekoa, but was lost in shipment and hence the rock was not tested. The quarry is owned and operated by George Hoffman. It is located within the town limits, about 300 yards from the station of the Oregon-Washington Railway and Navigation Company. The quarry face is 15 feet high and 100 feet long. The rock is coarse grained, hard, dark gray in color but weathers slightly brown.

A sample was secured from a basalt cut immediately north of Lamont, but was lost by the railway company in shipping to Seattle. Both north and south of Lamont the railway has made cuts in basalt varying in depth from 10 to 30 feet. The natural cliffs of the region do not often exceed 30 feet in height. The rock is quite uniform in character and of excellent quality. It is hard, fine grained, compact, and of a greenish black color. The rock is not distinctly columnar but has a regular jointing which splits it up into large blocks.

YAKIMA COUNTY.

GENERAL STATEMENT.

Yakima county has for its long western border the summit line of the Cascades; on its eastern margin it extends into the low plain of the Columbia. It has for its topography low plains, irregular plateaus and high mountains. The Yakima and its tributaries have in general very broad and open valleys. There are occasionally transverse ridges which these streams cross, producing water-gaps. The Yakima valley is bordered on opposite sides by plateaus. The plateau on the west gradually rises until it merges into the mountains.

In the lower and more accessible portions of the county there are two general varieties of rock. One of these is a series of sandstones and shales which represents sediments once deposited in a large lake. This material is so soft that it is worthless from the standpoint of road building. The other variety of rock is basalt which is of common occurrence at the water-gaps and in the canyons. Gravel is found rather generally over the lowlands. The larger streams have brought down extensive deposits of gravel from their highland tributaries.

Irrigation is necessary in all the lowland portions of the county to make sure of success in agriculture. Many thousands of acres are now under irrigation in the Yakima valley. Intensive farming is carried on, the chief products being fruit and hay. The farms are small and the rural population therefore large. In a very short time the irrigated portion of the county will support a dense population. The roads will be very numerous and will have a gridiron arrangement. It will at some time be necessary to macadamize the highways because of the heavy traffic upon them. Certain main lines of roads should be properly graded, surfaced with crushed rock, and placed in a first-class condition at once. The high value of the farm lands, the large number of people, and the abundant travel will warrant the construction of good roads on a large scale.

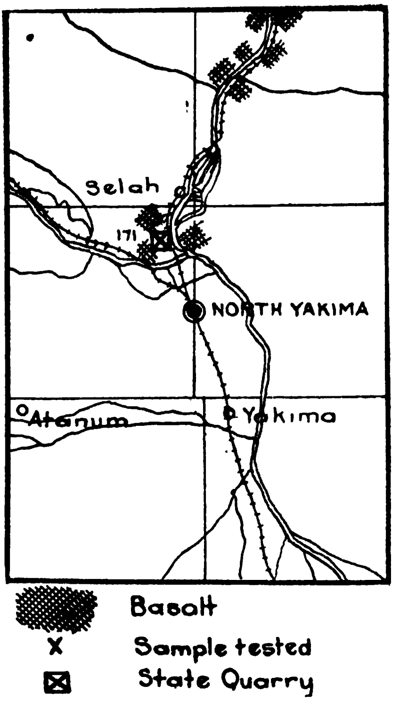


FIG. 50. Part of Yakima county, near North Yakima.
Scale, 1 inch equals 6 miles.

ROAD MATERIALS TESTED.

Serial Number 171.

This sample was taken from a basalt cliff 2 miles northwest of North Yakima, on the west side of the Northern Pacific Railway. At this locality Yakima river has cut through a high ridge, forming Selah gap. The walls of the gap rise about 500 feet above the river bank. On the west side of the gap the state owns a site for a quarry. It is located in the N. W. 1/4 of the N. W. 1/4 of section 12, T. 13 N., R. 18 E. At this place there is a small ravine or gully forming a reentrant in the rock cliff, which gives an excellent opportunity for the opening of a quarry and the installation of a crushing plant. The face of the rock cliff has the proper inclination and the height to permit of the operation of a crushing plant on a gravity plan. The overburden is so small as to be practically negligible. The rock is a dark gray, medium grained basalt, breaking with the usual shell-like fracture and sharp edges. About one-half of it is very compact and free from steam holes. In the remainder cavities of various sizes are more or less abundant. There is an abundance of first-class rock available so that those portions of questionable value need not be quarried. According to the test made upon the sample it is a hard, fairly tough rock, with high resistance to wear and fair cementing value. It should give good results when used as crushed rock for macadamized roads.

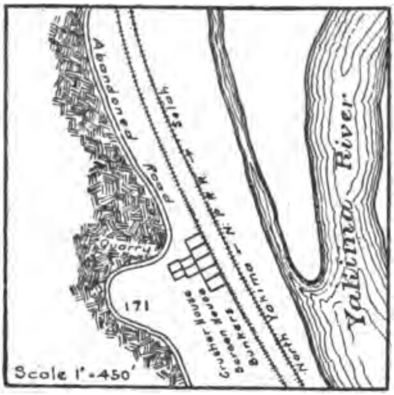


FIG. 51. Plan of the Selah state quarry and crushing plant, near North Yakima.

The state is opening a quarry and establishing a crushing plant at the above locality. The quarry floor is to be 80 feet above the level of the nearby railway track. The plant is to consist of a rock crusher, a revolving sorting screen, and a storage bunker. The crusher has a rating of 45 cubic yards of rock per hour; the storage bunker consists of 5 bins with a combined capacity of 750 cubic yards. The shipments from this plant will be wholly by rail.

INDEX

	Page
Adams County	40
Andesite	13
Asotin County	43
Basalt	14
Benton County	47
Cementing Value	32
Chehalis County	51
Chelan County	55
Clarke County	60
Coherency	28
Columbia County	63
Cowlitz County	66
Diabase	16
Diorite	17
Douglas County	74
Examination of Ledge	27
Ferry County	77
Fracture	29
Franklin County	85
Gabbro	17
Garfield County	88
Gneiss	23
Granite	18
Granodiorite	19
Grant County	90
Hardness	30
Igneous Rocks	13
Island County	95
Jefferson County	95
Jointing	29
King County	99
Kitsap County	106
Kittitas County	108
Klickitat County	113

Page

Laboratory Tests Upon Selected Samples........ 30
Lewis County 117
Limestone 21
Lincoln County 121

Marble 24
Mason County 128
Metamorphic Rocks 23
Mineral Constituents 28

Okanogan County 131

Pacific County 134
Pierce County 140
Porosity 28
Practical Use of Rock........ 29

Quartzite 25

Resistance to Wear........ 31
Rhyolite 20

Sandstone 22
San Juan County........ 144
Schist 26
Sedimentary Rocks 21
Serpentine 26
Skagit County 148
Skamania County 154
Slate 25
Snohomish County 157
Spokane County 162
Stevens County 168
Syenite 20

Tables—
  General Tests 33
  Tests upon Washington Rocks........34, 35, 36, 37, 38, 39

Texture 29
Thurston County 178
Toughness 31

Volcanic Ash 21

Wahkiakum County 182
Walla Walla County 186
Weight per Cubic Foot........ 32
Whatcom County 191
Whitman County 195

Yakima County 199

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